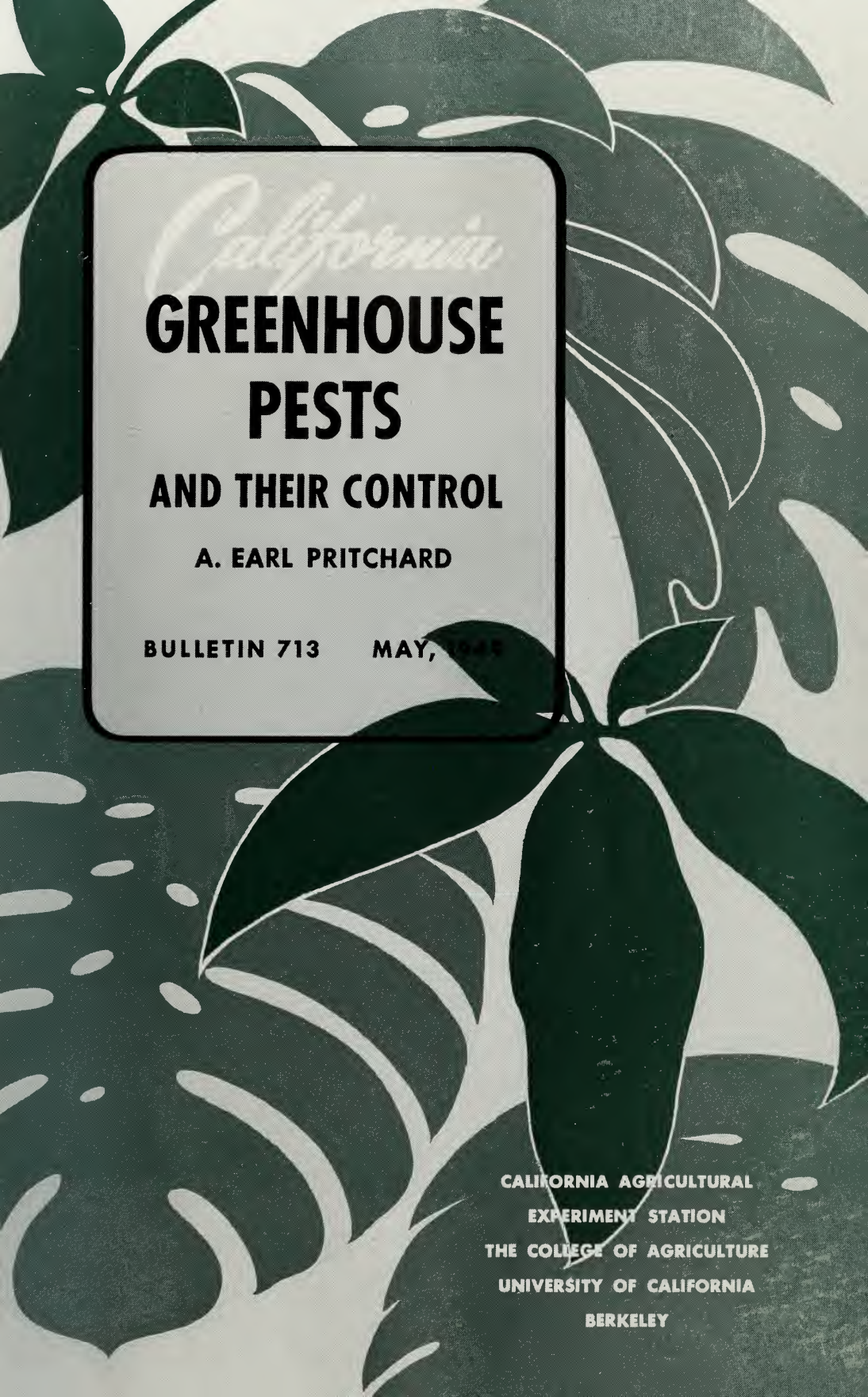

California GREENHOUSE PESTS AND THEIR CONTROL

A. EARL PRITCHARD

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WARNING

The organic phosphates (parathion, hexaethyl tetraphosphate and tetraethyl pyrophosphate) are exceedingly dangerous to human beings in extremely minute amounts when ingested, inhaled or absorbed through the skin. The precautionary statements contained in this publication concerning these materials may not be wholly adequate.

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At left: The Conservatory, Golden Gate Park, San Francisco.

This Bulletin

has been prepared as a source of information for the California greenhouseman in his fight against insect pests.

Investigation and observation in some of the most extensive commercial greenhouses in California have formed the basis of this publication. In the survey work, as well as in conducting experiments on the use of insecticides, the author has had access to the crops of a large number of successful greenhouse operators. These growers have given invaluable assistance to the studies.

The section on THE GREENHOUSE PESTS, with the many original photographs, will give the greenhouseman complete material to help him identify insect pests on his crops. This section clears up much of the confusion which has existed concerning the occurrence and the relative importance of certain species of insects and mites. Some species, not previously known to occur in California, are reported here for the first time.

It is important for the greenhouseman to learn to recognize the specific insect pests. This is true not only in understanding the actual importance of the pest involved, but also for deciding on the best measures for control. The newer insecticides in particular are often specific in their action, being effective for the control of one pest while not affecting a closely related species.

The sections on KINDS OF CONTROL and METHODS FOR APPLYING INSECTICIDES are intended as practical aids in carrying out the pest-control program. These sections are presented to provide an understanding of the methods involved.

The section on INSECTICIDES is believed to be as complete as possible in the light of present information. It describes all of the chemical controls which are in common use, as well as those which the greenhouseman may have heard about or those which he may have seen on labels of commercial products. It gives an evaluation of each with respect to its use in the greenhouse.

The reader is reminded that the recommendations for control should not be considered complete or final. The entire field of chemical control is constantly undergoing refinement, and information concerning the preparation and use of new materials is being augmented daily.

California

GREENHOUSE PESTS AND THEIR CONTROL

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THE CULTIVATION of flowering and other ornamental plants has become a tremendous industry in California during recent years. The cut-flower industry in the San Francisco Bay region alone has been estimated at $25,000,000 a year. A large amount of these crops are grown under glass. The San Francisco Bay region is particularly favored for greenhouse crops because of the comparatively mild climate throughout the year and the ready access to airplane transportation for eastern markets. About 8 million square feet of greenhouse space are located near San Francisco Bay.

In Los Angeles County there are over 2 million square feet of greenhouse space. While most of the cut flowers are grown out of doors, still those grown commercially under glass are worth about a million dollars annually.

There are also many amateur greenhouse-gardeners in the state. Near Los Angeles, particularly in the Hollywood hills and Pasadena, and along the peninsula south of San Francisco there are probably two thousand privately owned glasshouses, more than half of which are devoted to orchids.

Greenhouse Conditions Favor Pests

Ornamental plants are subject to the depredations of mite, insect, and other animal pests. The hothouse crops are grown under warm and humid conditions which favor the survival and development of many species which have been imported from tropical or semitropical regions. Such pests may be found exclusively in greenhouses, although many of these are found outdoors in the coastal and southern sections of California. Greenhouses are also subject to the invasion of native or established agricultural pests of the local neighborhood. Some may be infrequent or unimportant visitors, while others may become more serious because of the opportunity for year-around reproduction and protection from their natural enemies. This bulletin pertains to the important greenhouse pests which are introduced mainly by infested stock and also to the more important pests which are immigrants from outdoors.

Limitations of this Study

Certain woody plants, such as camellia and boxwood, are not generally considered to be greenhouse crops, although their propagation may be carried on in the greenhouse and pests attacking this stock may be found on the cuttings. A discussion of pests which are restricted to such plants is not included in this bulletin.

The treatment of the greenhouse pests and their control as given in this bulletin is intended to serve as an over-all guide. It has not been possible to include long host lists which are often available for many of the mites and insects. There is still a need for publications dealing with specific greenhouse crops, their individual pests, and specific control programs in relation to the crops.

SPIDER MITES
(Red-Spiders)

Importance: Spider mites, or red-spiders as they are commonly called, are among the most serious pests of ornamental plants. Because of their very small size and the general habit of feeding on the undersurface of leaves, their presence often escapes detection by the greenhouseman until they are exceedingly numerous and plant damage is obvious.

The needlelike mouthparts are used to puncture the tissues, and a speckled appearance of the leaves and flowers results. In the case of severe infestations, entire leaves may become bleached and curled, and leaf drop occurs.

Appearance: Spider mites are soft bodied, more or less elliptical, with the back arched and bearing bristles. The adult female is less than 1/50 inch in length. They are colored greenish, yellowish, or reddish, and often have dark spots on each side. The eggs are globular or flattened above and are pearly, amber, or red in color.

Fine strands of silk are spun by spider mites, although the webs may not be detected readily except when large numbers are present. When an infestation is very severe, parts of the plant may become completely enveloped in sheets of webbing, and masses of mites may hang from the tips of the leaves.

Development: Eggs are laid singly on the surface of leaves. An adult female may lay several or more eggs a day, producing as high as 50 to 100 eggs. During the course of development of the female three resting stages occur, each prior to shedding the skin. In a warm greenhouse an entire generation may be completed in from 7 days (at 80° F) to 14 days (at 70° F); but under cooler conditions a period of two or more months may be required.

Important Greenhouse Species

Two-spotted spider mite (common red-spider), *Tetranychus telarius* (Linnaeus), is greenish or yellowish, with a large, blackish spot on each side, or else reddish in color. It is the most general feeder and the most troublesome of the spider mites encountered by the floriculturist. Carnations, cymbidium orchids, gardenias, hydrangeas, and roses are greenhouse crops which are constantly subject to attack. Many other flowering and ornamental plants, as well as weeds, are susceptible to injury. This mite is found in abundance on many plants outside the greenhouse during the warmer part of the year.

It has been estimated that one female is capable of giving rise in one month's time to a progeny of 20 mites at 60° F, about 13,000 mites at 70° F, and well over 13 million mites at 80° F constant temperature. It is thus easy to see why multiplication is so rapid on hothouse crops and why control measures must be thorough.

Fig. 1. The two-spotted spider mite: adult female.

Fig. 2. Hydrangea enveloped in sheets of webbing made by an infestation of spider mites.

Other Species Found In California Greenhouses

Luden spider mite, *Tetranychus ludeni* Zacher, is bright reddish in color. Frequently it is found in greenhouses and is common outdoors in southern California. A number of flowering plants serve as hosts, of which lantana appears to be a favorite.

Palm spider mite, *Septanychus tumidus* (Banks), resembles the Luden spider mite but is considerably smaller. It often is a serious pest to greenhouse palms as well as to a few other plants such as maranta.

Asparagus spider mite, *Schizotetranychus asparagi* (Oudemans), is very small, pinkish, with dusky markings along each side. It is found only on asparagus ferns, causing the plants to become speckled or whitish.

Oxalis spider mite, *Tetranychina harti* (Ewing), is reddish, with bristle-bearing tubercles above and with very long forelegs. It occurs commonly on oxalis in greenhouses but does not transfer to other hosts.

CONTROL

Control of spider mites has long been a major problem in connection with greenhouse-grown cut flowers. Several rather recently developed acaricides have proved the most satisfactory, although each is subject to limitations. These include:

1. Azobenzene fumigation: high degree of control of all stages. (See page 49.)

2. Sodium selenate: excellent control over a long period of time on carnations. (See page 59.)

3. Tetraethyl pyrophosphate: effective for active stages. (See page 56.)

4. Parathion: excellent control. (See page 57.)

FALSE SPIDER MITES

Importance: The false spider mites are closely related to the spider mites, and they similarly injure foliage. Leaves show signs of their feeding by forming discolored flecks or depressions, and this may be followed by general discoloration and leaf drop.

Appearance: They are exceedingly small, flattened, red or yellowish mites. Adults are less than 1/100 inch in length. The eggs are elliptical, bright red, and are sometimes seen more readily than the mites. Unlike the spider mites, they do not spin silken webs.

Development: Eggs are laid singly on leaf surfaces. Under warm conditions, the eggs hatch in several days, and the life cycle may be completed in two weeks.

Fig. 4. Deep pits and silvering of the leaf caused by the phalaenopsis mite.

Fig. 3. The privet mite: adult female.

Important Greenhouse Species

Privet mite, *Brevipalpus inornatus* (Banks). Adult is bright red with a central darkening which forms two eye-like spots. The privet mite occurs on the undersurface of leaves. It is particularly destructive to azaleas and fuchsias in California greenhouses, although a number of other hosts have been noted.

Moderate to severe damage has been observed by a closely related species which feeds on several different orchids, while still another species is a pest of greenhouse palms.

Other Species Found In California Greenhouses

Phalaenopsis mite, *Tenuipalpus pacificus* Baker, is yellowish or reddish in color. It occurs only on phalaenopsis orchids, forming deep pits on the upper surface of the leaves. This species is found infrequently in California greenhouses, but it is a serious pest when present.

CONTROL

The false spider mites are not affected by the organic phosphate acaricides that are so effective for spider mites. Very little information on their control is available. Dimethyl carbinol has proved to give excellent control experimentally.

1. Sulfur or lime-sulfur: reported to give satisfactory control. (See page 59.)

2. Light oil with rotenone: effective control. (See page 56.)

THREAD-FOOTED MITES

Importance: The thread-footed mites comprise a small group which contains a few serious pests of ornamental plants. Growing tips of plants and young leaflets are characteristically deformed as a result of their feeding. The presence of these tiny mites in a greenhouse is seldom detected until a severe infestation has developed. Economic losses are due not only to the plant damage incurred but also to the labor and materials wasted in ineffective efforts for control.

Several species of thread-footed mites which are found in greenhouses are not known to be of economic importance. These are presumed to feed on decaying organic material or insects.

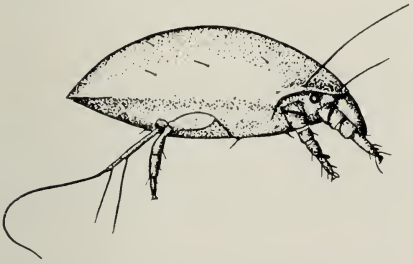


Fig. 5. The cyclamen mite: adult female.

Appearance: Adult mites are elliptical in shape, more or less flattened, brownish, and shining. They are not over 1/100 inch in length. The immature stages are white. The eggs are elliptical and white. It is by the characteristic damage that the presence of these mites is usually suspected.

Development: The eggs are laid on protected surfaces of the plant tissues where the mites are feeding. These hatch into six-legged larvae in from 3 to 7 days. The larval period is completed in from 1 to 4 days. A resting stage follows which lasts from 2 to 7 days before the adult emerges. The adult female may lay from 1 to 3 eggs during a day, and the total number laid by a single female ranges from 12 to 16. Breeding continues throughout the year under greenhouse conditions.

Important Greenhouse Species

Cyclamen mite, *Tarsonemus pallidus* Banks, feeds characteristically at the origin of new plant growth, in the buds or unfolding leaflets so that the leaves or flowers formed are aborted and mis-

Fig. 6. Crippled terminal growth of Hahn's ivy caused by the cyclamen mite.

shapen. In the case of plants such as African violet, gloxinia, and gynura, the "eyes" become whitish and growth is curtailed or stopped.

Optimum conditions for development of the mite are found in greenhouses where the temperature is moderately warm (60° to 80° F) and the relative humidity is very high (80 to 90 per cent). Lath house infestations are not apt to be severe.

The host range of the cyclamen mite is rather wide. English ivy is very commonly infested, and other plants such as aralia, fuchsia, azalea, pepper plant, and fibrous begonia are often infested. The only agricultural crop that is attacked is strawberry.

Other Species Found In California Greenhouses

Broad mite, *Hemitarsonemus latus* (Banks), is similar to the cyclamen mite in appearance and host range. It differs principally by occurring more generally over the plant and by feeding on the undersurface of leaves. This important pest of ornamentals is rarely encountered in California.

Bulb scale mite, *Tarsonemus laticeps* Halbert, infests the bulbs, stems, and leaves of narcissus. Damage is caused principally to the bulbs. This species is found only occasionally in California.

CONTROL

Control of the cyclamen mite is one of the most difficult problems encountered by growers of potted plants. The use of lauryl thiocyanate, ammonium polysulfide, lime-sulfur, or rotenone preparations, has not proved to give effective control in California. Dimethyl carbinol has shown some promise experimentally.

1. Parathion: considerable control when used as a wettable-powder spray. Several applications at weekly intervals are necessary. (See page 57.)

2. Hot water or vapor-heat treatment: effective when such treatment is practical. (See page 46.)

3. Methyl bromide fumigation: excellent control. (See page 55.)

LOUSE MITES

Importance: The louse mites constitute a small group which is closely allied to the thread-footed mites. They are often found on grasses or grains, but one of the common species feeds on injurious insects or sometimes annoys humans. The only species which is of importance in greenhouses is one which distributes spores of a fungus disease.

Appearance: These are soft-bodied mites. The abdomen of the female swells enormously, forming an egg-shaped or globular ball. They are whitish and become about 1/50 inch long.

Development: As many as 200 eggs are developed within the female mite. These eggs hatch and the young mites develop to maturity before they emerge from the parent.

Species Found In California Greenhouses

Grass mite, *Pediculopsis gramineum* Reuter, burrows into carnation buds to feed on the stamens and pistils. As they travel from plant to plant, they act as the principal agent for distribution of spores of the fungus causing carnation bud rot and "silver top" of grasses. This mite is found infrequently in California.

CONTROL

Manual picking and burning of infested buds constitutes the control measure which has been generally recommended. No information is available on the use of new acaricides.

FUNGUS MITES

Importance: Fungus mites are found commonly in rotting leaves and plant debris. Under greenhouse conditions where the relative humidity is high and the soil rich in decaying organic material and fungi, large numbers of these mites often occur. Generally they are associated with the soil or moldy plant tissue, but they also may be found crawling over the foliage. Only one member of this group is believed to be of economic importance to the floriculturist.

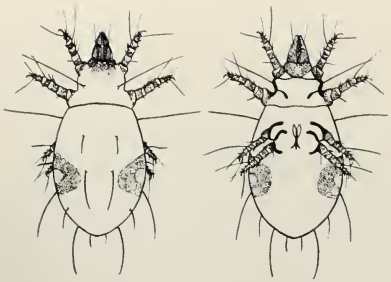


Fig. 7. Bulb mite: top and bottom views.

Appearance: These mites are somewhat egg-shaped, soft-bodied, with long bristles on the back. They are whitish and generally bear a pair of conspicuous brownish spots on the back part of the body. Adults may be as large as 1/50 inch in length.

Development: Eggs are laid singly where the adults are feeding, each female laying from 50 to 100 eggs. The eggs hatch within a few days, and the young mature in about two weeks. They are spread from place to place by means of a special form of the young which attaches itself to flies and other insects.

Important Greenhouse Species

Bulb mite, *Rhizoglyphus echinopus* (Fumouze and Robin), is similar to other fungus mites but larger and with short, stubby legs. This mite is found universally in many kinds of bulbs and tubers. It has been reported that healthy bulbs are attacked under certain conditions, but mite injury possibly follows a plant disorder. A fungus disease causing rot may be carried by the mite, however.

CONTROL

No information is available on the use of new acaricides on fungus mites. Eggs of the bulb mite are reported to withstand methyl bromide treatment.

1. Hot water or vapor-heat treatment: effective for bulb mite control. (See page 46.)

SPRINGTAILS

Importance: Springtails are found ordinarily under damp conditions where there is an abundance of humus. In greenhouses they may be common in the beds, in potting material, or under flower pots. Ordinarily their food consists of decaying organic material, fungi, or algae, but certain species may be responsible for injury to seedlings or young, tender plants. Only one species is known to be injurious in greenhouses. Many other species also occur which are not known to cause damage but which may become so abundant as to be a nuisance.

Appearance: Springtails are small, wingless insects, usually less than 1/5 inch in length. The immature stages are usually whitish. The adults are sometimes whitish, but often bluish, purplish, or yellowish with dark spots. Many species are able to jump by means of a lever which is attached underneath the body.

Development: Globular eggs are laid in small batches in the soil. As the young mature, they change only in size and color.

Important Greenhouse Species

Armed springtail, *Achorutes armatus* (Nicolet), is variable in color, but adults often are bluish or grayish. They are able to jump. This species is known to attack germinating seeds of greenhouse plants and particularly young ferns.

Fig. 8. A springtail insect which may be found where there is an abundance of humus.

CONTROL

Nicotine sulfate is effective against springtails which are contacted with the spray. More satisfactory control, however, may be obtained with certain of the newer insecticides.

1. Benzene hexachloride. (See page 50.)
2. Chlordane. (See page 51.)
3. Parathion. (See page 57.)

EARWIGS

Importance: Earwigs are usually scavengers, feeding on decaying plant material or on animal matter both dead and alive. One species, however, is a nuisance because it also chews all types of living plants in the gardens and greenhouses. Two other species occur in California greenhouses, but they are not known to be injurious.

Appearance: Earwigs are brownish, slender, and medium-sized, about 1/2 to 3/4 inch long. They possess a conspicuous pair of pincers at the back end. Wing covers, when present, are short and leathery.

Development: Earwigs are nocturnal in activity, hiding in the daytime in the soil or under trash, boards, or foliage. The females lay masses of oval, white eggs in small nests in the soil and then care for the eggs and young. There is one generation each year, reproduction occurring in the winter or spring.

Fig. 9. The European earwig. The male, at left, bears larger, strongly-curved forceps.

Important Greenhouse Species

European earwig, *Forficula auricularia* Linnaeus, is brownish and black with pale wing covers, legs, and antennae. This is an introduced species which has become a considerable pest during recent years.

CONTROL

Proprietary earwig baits give partial control of earwigs, but certain of the newer organic insecticides give excellent control.

1. DDT. (See page 52.)
2. Chlordane. (See page 51.)
3. Benzene hexachloride. (See page 50.)

TERMITES

Importance: Termites are sometimes reported to be greenhouse pests, not only by destroying benches and other wooden structures, but by gnawing and killing thick-stemmed plants such as geranium, chrysanthemum, begonia, and rose. They attack the mainstalk of the root just below the surface of the ground, tunneling it out or girdling it.

Appearance: The workers and soldiers are pale, soft-bodied, and wingless, about 1/4 inch in length. The soldier may be recognized by having the head and jaws strongly enlarged. Reproductive forms are black, about 1/2 inch in length, and they develop wings in the fall. Termites may be distinguished readily from ants by the lack of a slender waist.

Development: The workers and soldiers live in darkness, traveling in tunnels in the earth or wood or else in passageways which have been constructed with soil. Flying reproductive forms appear in the light after the first fall rains. These soon drop their wings and attempt the start of new colonies.

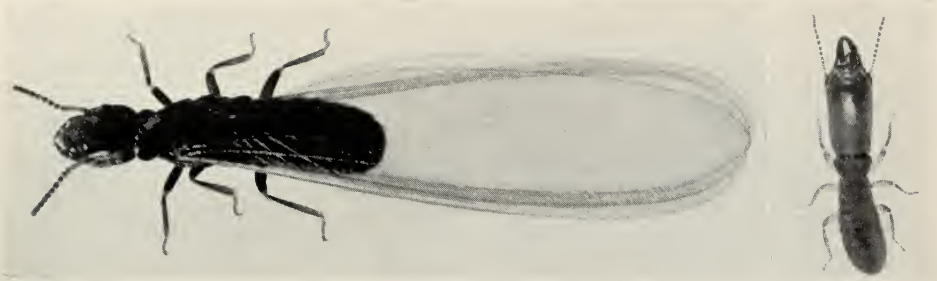


Fig. 10. The western termite. Left, a swarming individual, which will lose its wings when it has paired. Right, a member of the wingless, blind, and sterile soldier caste.

Species Found In California Greenhouses

Western termite, *Reticulitermes hesperus* Banks. The soldier of this species has a long and narrow, pale head. This is the common subterranean termite along the coast.

Black-legged termite, *Reticulitermes tibialis* Banks, is similar in appearance to the western termite, but the head of the soldier is short, broad, and yellow. This species is found characteristically in the more arid sections of California.

CONTROL

Plants may be protected against termite injury with certain of the newer insecticides which may be mixed with the soil.

1. DDT: excellent control. (See page 52.)

THRIPS

Importance: Thrips are important pests of ornamental plants. Either the foliage or buds and flowers are most commonly attacked, but bulbs and seeds also may be damaged. They feed on plant tissues by puncturing the surface and then sucking the liberated juices. A silvering of the leaves results. This may be accompanied by premature defoliation or else the flowers may be seriously blotched and streaked.

Certain species of thrips—the western flower thrips, the Moulton flower thrips, and the onion thrips—are of further importance because they serve as carriers of spotted wilt, a serious virus disease of many flowering plants. The nymphs of these thrips acquire the virus by feeding on an infected plant, and they are able to transmit the disease about one week later, after becoming adults.

Aside from the plant-feeding thrips which are found in greenhouses, there are several other species which are beneficial inasmuch as they feed on various pests.

Appearance: Thrips are slender, very small insects, ranging from 1/50 to 1/25 inch in length when grown. Adults are usually colored dark brown or yellowish, and the wings are banded with white in some species. Immature stages are usually whitish or yellowish with red eyes.

Thrips sometimes run rapidly, and some are able to hop. Adults are usually able to fly, although the very slender, feather-like wings may not be noted when they are folded over the back.

The presence of thrips on foliage may be recognized by the small black dots of excrement which they leave where they feed. These black dots are absent on leaves stippled by spider mites.

Development: From two weeks to two months are required for the completion of a generation, and breeding in greenhouses is continuous throughout the year. The tiny, bean-shaped eggs are laid within the more tender plant tissues, each female laying from 25 to 50 eggs. The eggs hatch in from 4 to 20 days, and two nymphal stages follow which last from 7 to 20 days. Two resting stages then occur, and these may be found where the nymphs were feeding or else in the ground below the plant. The resting stages together last from 4 to 14 days before the adult thrips appear.

Fig. 11. Left, silvering of the leaf is a characteristic result of thrips damage. This pest may similarly attack flower, bud, seed or bulb. Right, a healthy leaf and leaves affected by spotted wilt, a virus disease transmitted by thrips.

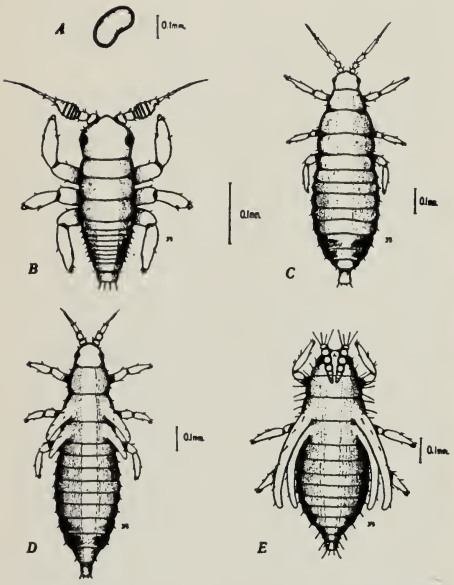


Fig. 12. Immature stages in the development of thrips: A, egg; B, newly emerged nymph; C, full-grown nymph; D, first resting stage; E, second resting stage.

Fig. 13. The greenhouse thrips: adult female.

Fig. 14. Adults and immature greenhouse thrips. Leaf blisters show where eggs have been laid in the tissue.

Important Greenhouse Species

Greenhouse thrips, *Heliothrips haemorrhoidalis* (Bouché), has the body dark brown with the back part much lighter in color; legs light yellow; and wings uniformly dusky except at base. The front portion of the body is covered with a strong network of lines. This thrips feeds almost entirely on the foliage, and large colonies may build up to cause severe damage. Although azaleas and fuchsias are particularly liable to attack, a wide variety of plants serve as hosts. Infestations are found outdoors in the coastal regions, but the adults rarely fly and migration is slow.

Western flower thrips, *Frankliniella occidentalis* (Pergande), is a tiny, yellowish species which enters the developing flowers of practically all types of plants. The blooms of cut flowers such as roses and carnations are particularly susceptible to malformation or streaking due to their feeding. When the outside flowers and weeds begin to dry up, definite migrations of the flower thrips occur, and greenhouses become infested.

Moulton flower thrips, *Frankliniella moultoni* Hood, is very similar to the western flower thrips, but generally dark brown. The two species are commonly found together.

Onion thrips, *Thrips tabaci* Lindeman, is very similar to western flower thrips in appearance and habits. It is apt to be present in larger numbers during the winter.

Other Species Found In California Greenhouses

Banded greenhouse thrips (sugar beet thrips), *Hercinothrips femoralis* (Reuter), is similar in appearance to the greenhouse thrips, but has three white bands on the forewings and the legs have dark brown basal segments. It is primarily a greenhouse pest, attacking the foliage of a wide variety of plants.

Dracaena thrips, *Parthenothrips dracaenae* Heeger, is similar in appearance to the banded greenhouse thrips, but paler and having only a single, complete black band on the forewings. This species is primarily a greenhouse pest, being found on the foliage of plants such as dracaena, palms, rubber plant, and philodendron.

Chrysanthemum thrips, *Thrips nigropilosus* (Uzel), is similar to the onion thrips, but bearing **X**-shaped flecks on the front part of the body. This species is found occasionally in the flowers of plants such as chrysanthemum and gloxinia.

Composite thrips, *Microcephalothrips abdominalis* (Crawford) is a uniform chocolate brown with light brown wings. It is frequently found in the flowers of various composite plants, particularly injuring the seeds.

Gladiolus thrips, *Taeniothrips simplex* (Morison), is very dark brown with the wings lighter at the base to give the appearance of a grayish band near the middle of the body. It is primarily a pest of gladiolus, feeding on the leaves, stems, and flowers. Minor infestations are found occasionally on other bulbous plants.

Lily thrips, *Liothrips vaneeckei* Priesner, is glossy black with silvery white wings. This species is found occasionally on lily bulbs.

Long-winged thrips, *Scirtothrips longipennis* (Bagnall), is orange yellow with dusky wings that extend well beyond the body. Feeding causes brown, corky lines on the leaves and stems and malformed flowers resembling injury by the cyclamen mite. Begonia and cyclamen are preferred hosts, but other plants may be attacked. It is found infrequently in California.

Yellow orchid thrips, *Taeniothrips xanthius* (Williams), is uniform pale yellow with brown wings. It feeds on the upper surface of cattleya leaves, and is found occasionally in California.

California orchid thrips, *Anaphothrips orchidii* (Moulton), is bright yellowish with light brown wings. It is occasionally found in California greenhouses on various orchids and plants similar to philodendron.

English orchid thrips, *Anaphothrips orchidaceous* Bagnall, is yellowish with brown crossbands on the abdomen. It is found occasionally in California, occurring on a wide variety of orchids.

CONTROL

In view of the fact that eggs are laid within plant tissues and the transformation stages may occur in the ground, the most satisfactory control of thrips is by means of an insecticide which possesses considerable residual action. Tartar emetic and brown sugar sprays are seldom used at the present.

1. DDT. (See page 52.)
2. Benzene hexachloride. (See page 50.)
3. Parathion. (See page 57.)

APHIDS

Importance: Aphids, or plant-lice, are well-known insects that infest nearly all types of plants. They are commonly found in colonies on the shoots of new growth, but they also occur under leaves, on stems, or on bulbs and roots. They injure the plants by sucking the juices with a long beak, and the new leaves are curled and crinkled by their feeding.

They also excrete a honeydew which may be produced in such quantities as to form a glistening coating on the leaves and branches. This honeydew attracts ants and promotes the growth of the black smut fungus.

Aphids also serve as the agents for transmission of a large number of plant virus diseases. The green peach aphid is known to transmit carnation streak, lily mottle virus, pansy and viola flower breaking, gladiolus mosaic, stock mosaic, ornithogalum mosaic, as well as mosaics in tritonia, babiana, ixia, sparaxis, streptanthera, and watsonia. The potato aphid, the cotton or melon aphid, the bean or dock aphid, the lily aphid, and the foxglove aphid also transmit certain of these viruses. Several other plant virus diseases such as narcissus mosaic, narcissus white streak, tigridia mosaic, and Easter lily necrotic fleck, are transmitted by certain of the latter aphids.

Appearance: Aphids are soft-bodied, usually with long legs and antennae, and ordinarily possessing a pair of tubes near the end of the body which are called cornicles. Adults are generally from 1/12 to 1/8 inch in length, and they are colored greenish, yellowish, pink, purplish, brown or black. Most species have winged as well as wingless forms.

Development: The life cycle of aphids is often complicated, and various species may differ considerably in details of development. Most of the aphids found in greenhouses, however, omit the egg stage entirely, and reproduction is continuous

Fig. 15. Effect of stock mosaic, a virus disease transmitted by certain aphids. Left, infected plant; right, healthy plant.

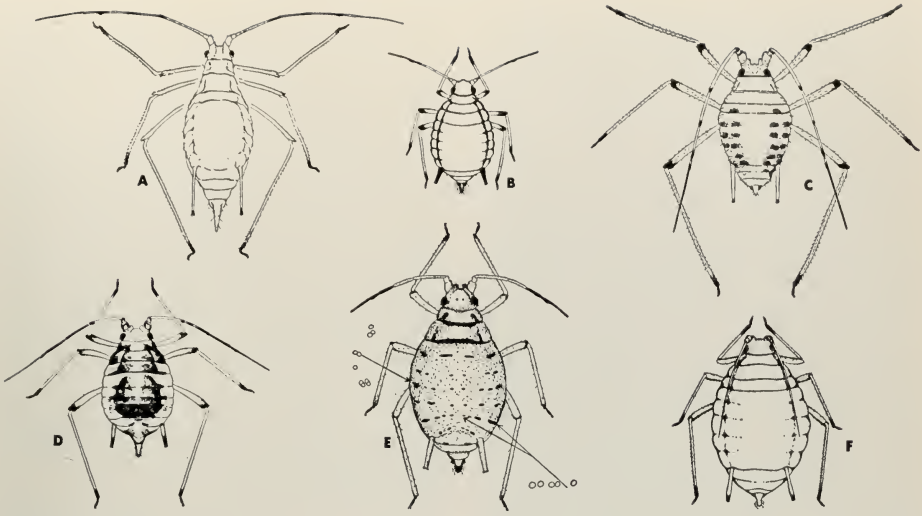


Fig. 16. Species of aphids of most importance in the greenhouse. A, pea aphid; B, cotton or melon aphid; C, foxglove aphid; D, lily aphid; E, ornate aphid; F, green peach aphid.

from unfertilized females. When the colony becomes overcrowded, winged forms may appear, and these fly to new food plants.

A single female may produce from 60 to 100 progeny before dying at an age of 20 to 30 days. The young in turn may mature in from 6 to 7 days after birth.

Important Greenhouse Species

Green peach aphid, *Myzus persicae* (Sulzer). The wingless form is slender and greenish. The winged form has a conspicuous, large, dusky blotch on the body. The cornicles are long and slender, slightly swollen before the tip. Nearly all of the greenhouse plants are subject to attack by this common aphid.

Lily aphid, *Myzus circumflexus* (Buckton), is similar to the green peach aphid, but the wingless form has a characteristic, horseshoe-shaped black marking on the back. This aphid is primarily a greenhouse pest. Although Easter lilies and tulips are particularly subject to attack, infestations are found commonly on a wide variety of other plants.

Ornate aphid, *Myzus ornatus* Laing. The wingless form is similar to the green peach aphid, but with interrupted, dusky lines across the back. This aphid is a common greenhouse pest, occurring on a wide variety of hosts.

Foxglove aphid, *Myzus solani* (Kaltenbach). The wingless form is similar to the green peach aphid, but with a dark greenish spot at the base of each cornicle. This aphid is a common, omnivorous feeder on greenhouse plants.

Cotton or melon aphid, *Aphis gossypii* Glover, is a small, rounded species which is greenish, yellowish, or mottled to blackish in color. The cornicles are short and dark. This species is very common, both in greenhouses and outside on a very wide variety of plants.

Bean or dock aphid, *Aphis rumicis* Linnaeus, is similar to the cotton or melon aphid, but always dull black and often with whitish spots on the back. Summer forms of this aphid enter greenhouses where they infest a wide variety of plants. Winter forms are restricted to dock, nasturtium, and several other plants.

Potato aphid, *Macrosiphum solanifolii* (Ashmead), is a large, slender aphid, usually either pink or green in color and often with a darker ridge down the back.

The cornicles are long and slender with black ends. Summer forms enter greenhouses to feed on a large variety of plants. The favorite winter host is rose.

Other Species Found In California Greenhouses

Chrysanthemum aphid, *Macrosiphum sanborni* (Gillette), is a large, slender, shining dark brown or black species. The cornicles are short, somewhat bottle-shaped. It is common, but infests only chrysanthemum.

Geranium aphid, *Macrosiphum pelargonii* (Kaltenbach), is similar to the potato aphid, but only green in color. It is restricted to geranium and is often abundant on the growing tips.

Pea aphid, *Macrosiphum pisi* (Kaltenbach), is similar to the potato aphid, but only green in color. It is restricted to legumes, often being injurious to sweet peas.

Rose aphid, *Macrosiphum rosae* (Linnaeus), is similar to the potato aphid, but the cornicles are black. It is found commonly on roses, either outside or in greenhouses, preferring the tender shoots and buds.

Small green rose aphid, *Myzaphis rosarum* Walker, is much smaller than the rose aphid, plumper, and always greenish in color. It is more likely to be distributed over the plant, rather than preferring new shoots. Attacks are confined to certain varieties of roses.

Fern aphid, *Idiopterus nephrolepidis* Davis, is a small, black species with whitish legs and clouded wing veins. It is often taken on maidenhair, holly, Boston, and brake ferns, occurring both in greenhouses and outside.

Violet aphid, *Micromyzus violae* (Pergande), is dark reddish or brownish, with clouded wing veins and club-shaped cornicles. Although it is widely distributed, infestations are restricted to violets. It is sometimes a serious pest.

Black citrus aphid, *Toxoptera aurantii* (Fonscolombe), is a plump, dark brown aphid with distinctive wing venation. It is a common pest of camellias which sometimes enters greenhouses to feed on gardenias and various tropical plants.

Banana aphid, *Pentalonia nigronervosa* Coquerel, is a peculiar species with clouded wing veins. It is found occasionally in greenhouses on various tropical plants.

Tulip leaf aphid, *Amphorophora tulipaella* (Theobald), is a bright green species with the cornicles dark green and strongly swollen near the middle. It was introduced on tulip bulbs, originally from Holland, and it is sometimes a pest to this crop.

Periwinkle aphid, *Rhopalosiphoninus latysiphon* (Davidson), is similar to the tulip leaf aphid, but the cornicles are paler and with the swelling very abrupt. This aphid is frequently a pest of tulips.

Ivy aphid, *Aphis hederae* Kaltenbach, is similar to the cotton or melon aphid, but dark pur-

Fig. 17. The ivy aphid on terminal growth of English ivy. The enlarged, pale aphids are parasitized.

plish, dark greenish, or blackish. It is found commonly on the tender tips of English ivy, both in the greenhouse and outside.

Leaf-curl plum aphid, *Aphis helichrysi* Kaltenbach, is similar to the cotton or melon aphid, but only pale green in color. The summer forms deform the leaves and buds of chrysanthemum, cineraria, and other composite plants, particularly in southern California.

Tulip bulb or iris root aphid, *Aphis tulipae* (Fonscolombe), is similar to the cotton or melon aphid, but the wingless forms are covered with a fine, white, powdery wax. It infests many liliaceous plants, feeding chiefly under the leaf sheaths at the base of the plant and on bulbs and rootstalks. This aphid is common throughout California, and it is particularly injurious to bulbs in storage.

Aster root aphid, *Aphis middletonii* Thomas, is similar to the cotton or melon aphid, but dark green. It commonly infests the roots of various composite plants.

Apple-grain aphid, *Rhopalosiphum prunifoliae* (Fitch), is similar to the cotton or melon aphid, but greenish with reddish areas at the back end. It is frequently found on tulips, strelitzia, and similar plants under greenhouse conditions.

Latania aphid, *Cerataphis lataniae* (Boisduval), is a wingless form with very short legs and a dark, elliptical body which bears a dense, marginal fringe of white, waxy threads. This form bears more resemblance to a young whitefly than it does to an aphid. A winged form is found occasionally, however, which bears more resemblance to aphids. This species is found only in greenhouses, occurring frequently on orchids, palms, and ferns.

CONTROL

Aphids often are very easy to kill, although repeated applications may be necessary to keep them controlled. The newer insecticides frequently are effective only against certain species.

1. Nicotine: most commonly used as a spray or a smoke. (See page 58.)

2. Light-oil emulsions, containing rotenone, nicotine, or pyrethrum: more often used outdoors. (See page 56.)

3. Calcium cyanide fumigation: an important method of control. (See page 51.)

4. Tetraethyl pyrophosphate: kills most aphids very rapidly. (See page 56.)

5. Benzene hexachloride: effective for certain species and possesses a residual action. (See page 50.)

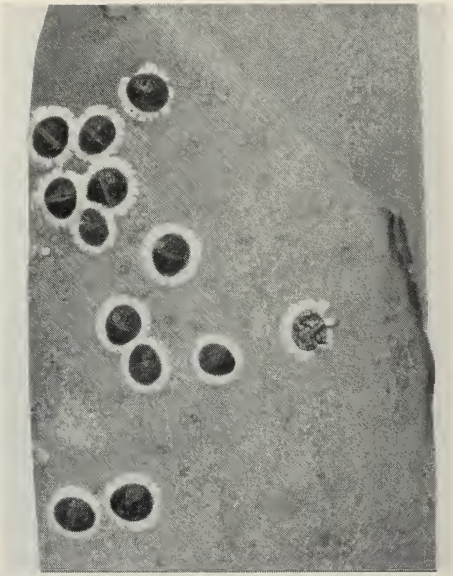


Fig. 18. The latania aphid is found on orchids, palms, and ferns.

6. Parathion: excellent control with some residual action. (See page 57.)

7. DDT: effective for the pea aphid. (See page 52.)

WHITEFLIES

Importance: Whiteflies feed exclusively on leaves, nearly always occurring on the undersurface. They suck juices from the plants, and also excrete large quantities of honeydew in which sooty mold grows.

Appearance: The adults are moth-like and covered with white, waxy powder. They are about 1/16 of an inch in length. The immature stages resemble miniature scale insects. They are flat and oval, light yellowish or greenish, and often provided with a fringe of wax threads.

Development: The oval eggs are attached to the leaves by means of short stalks, and they are sometimes arranged in circles. Hatching takes place in 10 to 14 days, and the young crawl a short distance before settling down. After feeding for about two weeks, a transformation stage is formed which lasts another two

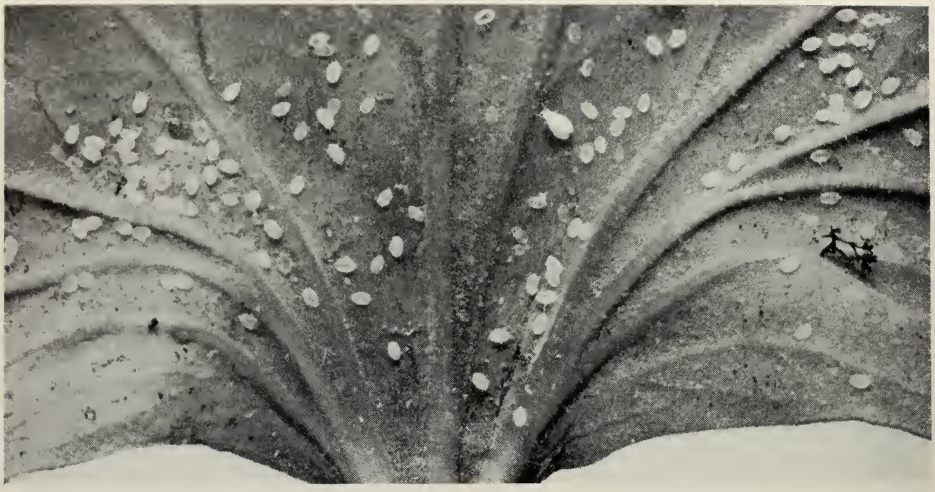


Fig. 19. Immature stages and adults of the greenhouse whitefly on underside of geranium leaf.

weeks. The adult female lives about one month, laying from 50 to 150 eggs.

Important Greenhouse Species

Greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood). Immature stages are pale greenish, semitransparent, and the covering of the transformation stage is armed with long and short transparent threads. Adults are pure white. It is a common greenhouse pest throughout the country, and in California also is found in lath houses and gardens. A very wide variety of plants may be infested, particularly pelargonium, fuchsia, bouvardia, hibiscus, and lantana.

Other Species Found In California Greenhouses

Iris whitefly, *Aleyrodes spiraeoides* Quaintance. Covering of transformation stage is yellow, devoid of any fringe. Adults are white with two dusky spots on each of the fore wings and one spot on each of the hind wings. Although primarily a pest of iris, it also infests a variety of other ornamental plants and weeds. This species is common, being most abundant outdoors in the late summer and fall.

Fern whitefly, *Aleurotulus nephrolepidis* Quaintance. Covering of transformation stage is bright yellow, without any fringe. Adults are pure white. This species is found infrequently on various ferns in greenhouses and homes.

Azalea whitefly, *Aleyrodes azaleae* Baker and Moles. Covering of transformation stage is light yellowish, without waxy secretions. Adults are uniform pale yellow. Although found on azaleas throughout California, it does not appear to be a very serious pest.

Citrus whitefly, *Dialeurodes citri* (Riley and Howard), is similar in appearance to the greenhouse whitefly, except lacking the threads on the covering of the transformation stage. It is a serious pest to citrus and many ornamentals. It has been introduced into California several times, but eradication measures are employed whenever it is found. This whitefly is commonly intercepted in quarantine and may be regarded as a potential greenhouse pest.

CONTROL

Until recently whiteflies have been difficult to control except with considerable effort.

1. Calcium cyanide fumigation: the method most commonly employed. (See page 51.)

2. Nicotine sprays or oil combinations with nicotine or pyrethrum: some degree of success. (See page 58.)

3. Tetraethyl pyrophosphate: effective against adults only. (See page 56.)

4. DDT: effective against adults or against all stages when combined with oil. (See page 52.)

5. Parathion: excellent control when used as a spray; kills only adults when used as an aerosol. (See page 57.)

MEALYBUGS

Importance: Mealybugs are among the most serious of greenhouse pests. They injure plants by sucking the sap with their needle-like mouthparts. The masses of wax from their bodies and their cottony egg sacs or cocoons render the plants unsightly. The honeydew they excrete attracts ants and serves as a medium of growth for sooty mold, making the flowers or plants even more unsalable. The constantly recurring use of insecticides and labor for their control has made their cost to the grower still greater.

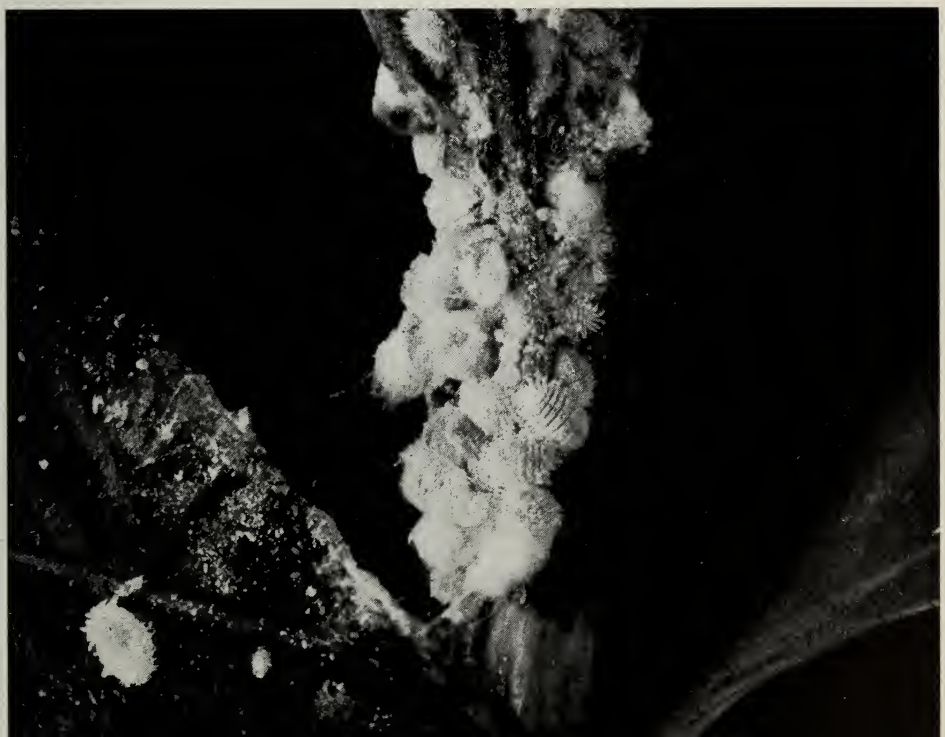
Appearance: Mealybugs are soft-bodied scale insects which are more or less covered with a whitish or yellowish, powdery wax. They are usually from 1/5 to 1/3 inch in length when mature. Waxy filaments are often formed around the body, or, in some cases, humps of wax are formed. Mealybugs retain their legs and are able to move around, although slowly, throughout life.

Development: Females may lay masses of several hundred yellowish or orange eggs in white, cottony sacs. In some species, however, living young are produced. Egg laying, when this occurs, extends over a period of about ten days, and the eggs commence to hatch in about two weeks. From six weeks to two months are required for the young females to reach maturity. The young male forms a cottony cocoon two or three weeks after emerging from the egg stage and therein develops into a transformation stage. The adult male which emerges in a week or ten days has a pair of delicate wings and is able to fly to the females for fertilization. All stages ordinarily may be found under greenhouse conditions, due to the constant overlapping of generations.

Important Greenhouse Species

Citrus mealybug, *Pseudococcus citri* (Risso), is heavily and evenly covered with white, powdery wax except for a fainter, narrow streak down the middle. Short filaments are present along the sides, the hind ones being about one fourth the length of the body. Irregular, cottony egg masses are laid which contain as many as 500 eggs. This mealybug is the one most commonly found on gardenia, bouvardia, and stephanotis, but

Fig. 20. The citrus mealybug, which has a large host range on ornamental plants.



its host range on ornamental plants is very large.

Mexican mealybug, *Phenacoccus gossypii* (Townsend and Cockerell), is covered with white, powdery wax except for four rows of thinly waxed depressions down the back. Short filaments are present along the sides, the hind ones being about one fourth the length of the body. A grayish, watery fluid is ejected from pores on the back when it is irritated. The cottony egg masses are large and uniform. This species is found commonly on pelargonium and fuchsia, as well as a wide variety of other host plants.

Grape mealybug (Baker mealybug), *Pseudococcus maritimus* (Ehrhorn), has the body thickly and evenly covered with white, powdery wax, the segments being rather sharply defined. The marginal filaments are short, although the terminal ones are one half as long as the body or longer. The egg masses are large and irregular. The grape mealybug is a common greenhouse pest, occurring on a wide variety of plants but particularly on Boston ferns. It is of special importance because it usually occurs on the roots as well as on the foliage.

Long-tailed mealybug, *Pseudococcus adonidum* (Linnaeus), has the body thinly covered with white wax with a broad, fainter stripe down the middle. Filaments along the sides are often one half the width of the body, and the terminal ones are as long as the body or longer. No eggs are laid, and living young are produced. This species is chiefly a greenhouse pest, although it is common outdoors in southern California. Dracaena is a favorite host, but it may occur on a wide variety of plants.

Ground mealybug, *Rhizoecus falcifer* Künkel, is very small with the body evenly covered with white wax and without filaments. It is found in the soil, working on the roots of a large variety of plants. Palms and cacti are favored hosts under greenhouse conditions.

Fig. 21. The Mexican mealybug on geranium.

Fig. 22. The grape (or Baker) mealybug.

Fig. 23. The long-tailed mealybug on dracaena.

Fig. 24. The ground mealybug works on roots.

Fig. 25. The palm mealybug on a Kentia palm leaflet. Immature stages, adult females, and male cocoons are shown.

Fig. 26. The striped mealybug on nephthytis.

Other Species Found In California Greenhouses

Citrophilus mealybug, *Pseudococcus gahani* Green, is similar in appearance to the Mexican mealybug in having four rows of thinly waxed depressions down the back, of which the middle pair is most conspicuous. The body fluid, however, is clear and red. Large egg masses are laid. This species prefers cooler temperatures, and is more apt to be a serious pest outdoors. It is often found in greenhouses, however, on such hosts as English ivy and rubber plant.

Palm mealybug (coconut mealybug), *Pseudococcus nipae* (Maskell), has the body covered with cream-colored or yellowish wax which forms rows of humps. Filaments are absent. No eggs are laid. The palm mealybug is found particularly on palms, although other tropical plants sometimes serve as hosts. It is found chiefly in greenhouses, but is common outdoors in southern California.

Striped mealybug, *Ferrisia virgatus* (Cockerell). The body is dark purple and thinly covered with white powder except for two black, broken lines down the back. Numerous long and very delicate filaments are secreted. It ordinarily rests with most of the body held elevated from the plant. No eggs are laid. This species is found occasionally in California greenhouses on such plants as nephthytis and croton. It is eradicated whenever recognized.

Amaryllis mealybug, *Trionymus peregrinus* (Green). The body is grayish with a coating of white, powdery wax except for thinner crossbands. This species is found infrequently, occurring only on clivia or related amaryllis-like plants. It lies concealed between the bases of the leaves, surrounded by masses of wax.

CONTROL

Mealybugs are often very difficult to control, particularly those species which lay eggs. High-pressure sprays are most satisfactory, and water alone will often check a serious infestation. Ant control (see page 42) should be practiced in connection with mealybug control. It is worthy of note that the citrus mealybug has been eliminated from some gardenia ranges which have been regularly treated with DDT.

1. Light-oil emulsions: nicotine or other plant derivatives are often included. (See page 56.)

2. Parathion. (See page 57.)

3. Biological control: cryptolaemus beetles. (See page 46.)

ENSIGN SCALES

Importance: The ensign scales are a small group of mealybug-like insects which feed on plants by sucking the juices. They also excrete honeydew. Only one species is of importance in greenhouses.

Appearance: They are dark colored with long legs and with conspicuous, snow-white plates symmetrically arranged on the body. Adults are about 1/12 of an inch in length. The characteristic egg sac is slender with longitudinal ridges, composed of white wax and attached to the back end of the insect.

Development: There are about five generations in a year. The female is about nine weeks old when eggs are first laid.

Species Found In California Greenhouses

Greenhouse orthezia, *Orthezia insignis* Douglas, is dark green or brown with broad, white plates along each side and in two rows down the back. Its egg sac is about twice the length of the body. It is found infrequently in California greenhouses and also occurs outdoors in southern California. A wide variety of plants are subject to infestation.

CONTROL

The control measures which are used for mealybugs are used also for the greenhouse orthezia.

Fig. 27. The cottony-cushion scale on Japanese pittosporum.

Fig. 28. Young and adult females of the greenhouse orthezia on bignonia.

GIANT SCALES

Importance: The giant scales are mealybug-like insects which feed on plants by sucking the juices. They also excrete large quantities of honeydew. Only one species is of importance as a pest of ornamentals.

Appearance: Adult females of the pest considered here are about 1/3 inch in length, reddish in color, and more or less covered with a whitish powder. The characteristic egg sac is very large and broad with longitudinal ridges. It is composed of white, cottony wax.

Development: From 500 to 800 eggs are laid by a single female. The young settle on the branches and leaves and mature in about four months.

Species Found In California Greenhouses

Cottony-cushion scale, *Icerya purchasi* Maskell, was introduced into California from Australia, following which it became a serious pest of citrus and many ornamentals. Its general spread and build-up have been remarkably controlled by means of the Australian ladybird beetle and a cryptochaetum fly parasite. It is found infrequently in greenhouses on such plants as croton, geranium, ivy, and poinsettia. Japanese pittosporum is a favorite host.

CONTROL

The cottony-cushion scale is very difficult to control with insecticides except for one of the new organic phosphates:

1. Parathion: excellent control. (See page 57.)

Fig. 29. Cottony sacs of the woolly cactus scale.

WOOLLY-SAC SCALES

Importance: The woolly-sac scales are a small group of mealybug-like insects which injure ornamentals by sucking the plant sap. No honeydew is excreted by the greenhouse species.

Appearance: Active stages are purplish or reddish and more or less coated with a whitish, powdery wax. The full-grown female is enclosed in an elliptical, woolly sac, about 1/8 inch in length, while the male cocoons are noticeably smaller.

Development: From 50 to 200 eggs are laid in the sac covering the adult female. The young crawl to the stems or axils of the leaves and grow very slowly. There is but one generation each year, although all stages are usually present under greenhouse conditions.

Species Found In California Greenhouses

Woolly azalea scale, *Eriococcus azaleae* Comstock. Azaleas and rhododendrons are the usual hosts. This species has been reported from California several times.

Woolly cactus scale, *Eriococcus coccineus* Cockerell. Various cacti serve as hosts, the cottony sacs occurring commonly on the spines. It is a common pest in California, both outside or under greenhouse conditions.

CONTROL

The only satisfactory control of woolly-sac scales has been obtained with one of the new organic insecticides.

1. Parathion: excellent control. (See page 57.)

SOFT SCALES

Importance: Soft scales are important greenhouse pests, not only because they suck the plant juices, but also because of the sooty mold which grows in the honeydew that they excrete. They are often present in large numbers.

Appearance: Partially grown individuals are flattened, elliptical, shining, and rubbery. Adult females may be rubbery or hardened, and flattened or globular in shape. They are from 1/12 to 1/3 inch in length. A cottony, white egg sac is formed in certain species.

Development: As many as several thousand eggs may be laid by one female over a period of six weeks to two months. These are usually deposited under the body, although a cottony egg sac is sometimes formed. Eggs usually hatch in from 1 to 3 weeks after they are laid. In certain cases, living young are produced. The crawlers wander over the plant for several days before settling down. Gradual growth then takes place, the females maturing in a period of from several months to nearly a year. The ability to move about sometimes occurs throughout a large part of the development.

Important Greenhouse Species

Soft brown scale, *Coccus hesperidum* Linnaeus. The adult female is rather flattened, soft and pliable, and shining yellowish or brownish with a somewhat

Fig. 30. Adults and young of the soft brown scale. Sooty mold grows on the insect excretions.

Fig. 31. Adult females of the hemispherical scale on fern.

mottled appearance. Living young are produced. It is primarily a greenhouse pest, although it also is destructive outdoors in California. Practically all types of greenhouse plants serve as hosts.

Hemispherical scale, *Saissetia hemisphaerica* (Targioni). Adult females are strongly convex, hard, brown, smooth and shining. The skin is covered with tiny, round, pale areas. The undersurface of the female forms a cup as a tremendous number of eggs piles up. A great many plants are subject to attack, ferns being one of the favorites.

Other Species Found In California Greenhouses

Elongate soft scale, *Coccus elongatus* (Signoret), is similar in appearance to the soft brown scale, but the body is considerably more elongate as a rule. Living young are produced. It is not as commonly encountered as that species, and it is more restricted to greenhouses. A variety of tropical plants serve as hosts, palms being one of the favorites.

Orchid soft scale, *Coccus pseudohesperidum* (Cockerell). Adult female is elliptical and flattened, leathery, black, with a narrow yellowish margin, and with thin patches of wax on the back. Living young are produced. This scale is generally distributed on orchids in California greenhouses, dendrobium being a favorite.

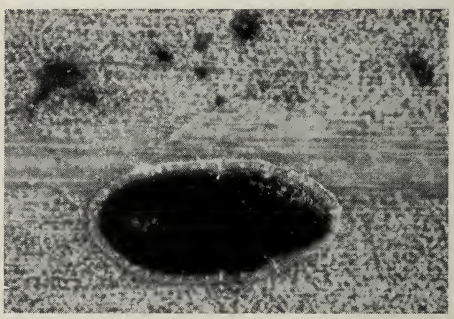


Fig. 32. The orchid soft scale on leaf of dendrobium orchid.

Tessellated scale, *Eucalymnatus tessellatus* (Signoret). The adult female is elliptical and flattened, greenish black and with a network of pale lines. Reproduction is by eggs, but the young emerge from the thin shells immediately after deposition. It is found almost entirely in greenhouses on various tropical plants.

Nigra scale, *Saissetia nigra* (Nietner). The adult female is elliptical, flattened, hardened, and black, the skin being covered with small, irregularly divided pale areas. A large number of eggs are laid beneath the female during the period of June until February. This species is frequently found in greenhouses, although it is a serious pest outdoors along the coast. Woody plants, such as ivy, holly, and Japanese aralia, are preferred hosts.

Black scale, *Saissetia oleae* (Bernard). The adult females are globular, hardened, and with

ridges on the back that form the letter "H." The skin is covered with tiny, rounded, pale areas. Very large numbers of eggs are laid beneath the body of the female. Although frequently found in greenhouses, it is a more serious pest outdoors. A very wide variety of plants are attacked, but woody stems are preferred.

Pyriform scale, *Protopulvinaria pyriformis* (Cockerell). The adult female resembles the soft brown scale but forms a cottony sac which appears as a white fringe around the body. An infestation of this pest was recently found in a greenhouse in southern California, although it was probably eradicated. Woody ornamentals are favored hosts.

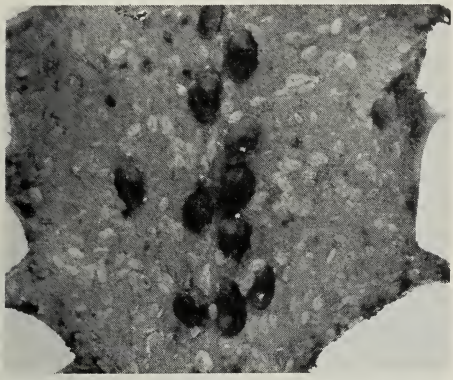


Fig. 33. The nigra scale on English holly.

Fig. 34. The cottony orchid scale with its egg sac on a leaf of dendrobium.

Cottony camellia scale, *Pulvinaria floccifera* Westwood. Mature females are light brownish, elliptical, flattened, and soft. A characteristic long and slender, usually curved egg sac is formed from a white, cottony material. Camellias are the preferred host, but it has been found on ferns and podocarpus under greenhouse conditions.

Cottony hydrangea scale, *Pulvinaria hydrangeae* Steinweden. Resembles the cottony camellia scale, but is found characteristically on hydrangea throughout California.

Cottony orchid scale, *Pulvinaria phaiae* Lull. Resembles the cottony camellia scale, but occurs only on orchids. It is found occasionally in California.

Cottony guava scale (green shield scale), *Pulvinaria psidii* Maskell. Closely resembles the cottony camellia scale. A serious pest of guava and certain woody ornamentals which is occasionally found in California greenhouses.

CONTROL

Soft scale insects are very difficult to control, particularly under greenhouse conditions where the young are not produced at definite seasons.

1. Light-oil emulsion: the most effective spray where this can be used. (See page 56.)

2. Calcium cyanide fumigation: some degree of control. (See page 51.)

3. Parathion: effective against young of soft scales, but not effective for "rubbery" stages. (See page 57.)

Fig. 35. Adult females of the black scale on English holly.

ARMORED SCALES

Importance: Armored scales are very serious pests of ornamental plants. They not only suck the plant sap, but their feeding is often accompanied by a toxic effect to the plant. No honeydew is excreted.

Appearance: Armored scales are characterized by possessing a hardened shield, or scale, above the body. The shields are more or less flattened, usually about 1/12 to 1/8 inch in diameter. They are circular in shape, or else elliptical or oystershell-like.

Development: Reproduction may be by eggs, from several dozen to several hundred being laid beneath the shield over a period of a month or two. In some cases, living young are produced. The newly emerged crawlers are active for several hours or for a day or two. After settling down, they lose their legs and remain stationary for the rest of their development. There are commonly from 3 to 7 generations a year.

In the course of female development, the discarded skin of the settled crawler forms the nipple of the shield. The covering of the second stage forms a ring around this. The larger part of the shield ordinarily is secreted by the third stage which becomes the mature female. The shape, color, and texture of the shield, together with the position of the nipple and comparative sizes of the rings, are useful in recognizing the species.

The nipple, together with the secretion of the second immature stage, forms the covering of the male. Adults of this sex emerge as delicate, winged insects. The male shields are smaller and more elongate than those of the female. They either resemble the female shield in color and texture or else they are cottony white with three longitudinal ridges.

Important Greenhouse Species

Ivy scale (oleander scale), *Aspidiotus hederae* (Vallot). The shield of the female is more or less circular, flattened, whitish in color, and with the nipple more or less central. Shield of the male is similar but smaller and more elongate. This scale is a very common pest, both in greenhouses and outside. The leaves and stems of a wide variety of plants may be infested.

Florida red scale, *Chrysomphalus ficus* Ashmead. The shield of the female is thin, circular, flat, with a central nipple, and dark mahogany red in color. Shield of the male is smaller, more or less oval, somewhat lighter in color. It is common in greenhouses throughout California. It is found on the leaves of a wide variety of plants, particularly palms and rubber plant.

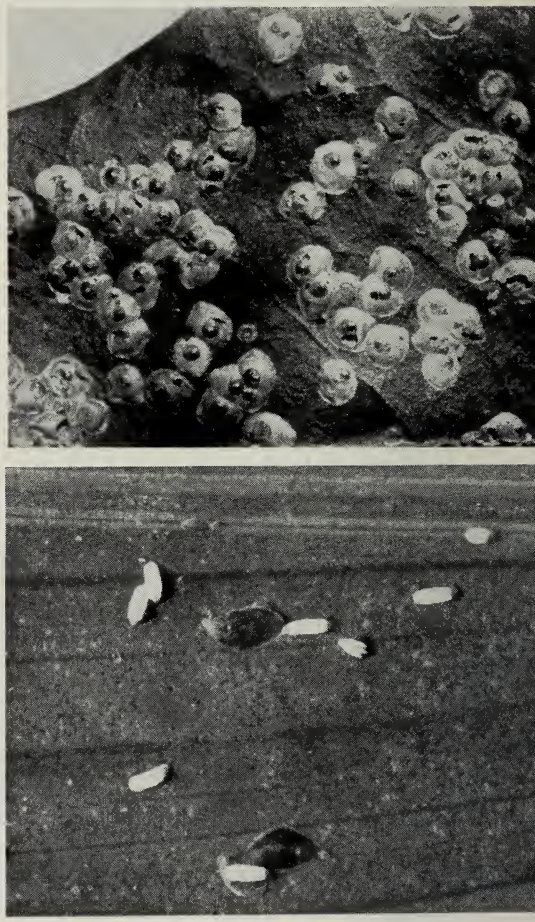


Fig. 36. Above, the ivy scale. Below, the aspidistra scale, showing white, elongate males and brown, oystershell-shaped females.

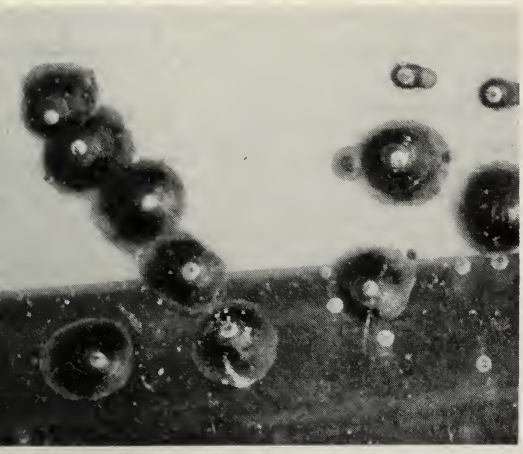


Fig. 37. The false Florida red scale on aspidistra.

Boisduval scale, *Diaspis boisduvalii* Signoret. The shield of the female is more or less circular, flat, thin, whitish, and with the nipple more or less central. Shield of the male is small, elongate, white, bearing three ridges, and with nipple terminal. The males are found commonly clustered together in a cottony mass. Cattleya and cymbidium serve as the most common hosts, although other orchids and certain tropical plants may be attacked. This species often encrusts the stems, and heavily infested leaves turn yellow and die.

Aspidistra scale (fern scale), *Pinnaspis aspidistrae* (Signoret). The shield of the female is brown, broadly oystershell-shaped with terminal nipple. Male shield is small, elongate, and felted white. This is a common greenhouse pest, occurring on a wide variety of plants but particularly aspidistra and ferns.

Other Species Found In California Greenhouses

Cyanophyllum scale, *Hemiberlesia cyanophylli* (Signoret), closely resembles the ivy scale. It is often found in greenhouses, but also occurs outdoors in southern California. A large number of tropical plants may be infested.

Latania scale, *Hemiberlesia lataniae* (Signoret), closely resembles the ivy scale, except the female shield is evenly and strongly convex and the body of the insect usually remains in the shield when it is removed. It is sometimes abundant on palms, but a wide variety of other plants are attacked.

Greedy scale, *Hemiberlesia rapax* (Comstock), resembles the ivy scale except the female shield is strongly convex with the apex of the hump off to one side. Primarily a greenhouse pest in many parts of the United States, but found more commonly outdoors in California. It occurs on a wide variety of woody ornamental plants, chiefly infesting the stems and particularly the axils of the leaves and bases of the buds.

Dictyospermum scale (Spanish red scale), *Chrysomphalus dictyospermi* (Morgan), is similar to the Florida red scale, but the shield of the female is yellowish or light brownish. It is primarily a greenhouse pest, although occurring outdoors in southern California. It has been noted on various palms, as well as a wide variety of other plants.

False Florida red scale, *Chrysomphalus bifasciculatus* Ferris. Shield of the female is very similar to that of the Florida red scale, but dark chocolate brown in color. It is frequently found both in greenhouses and outdoors over most of California. Aspidistra is a favorite host, although many other plants may be infested.

California red scale, *Aonidiella aurantii* (Maskell). The shield of the female is similar to that of the Florida red scale, but bright reddish in color. Body of female is bean-shaped. It is an important pest of citrus which is sometimes found on various greenhouse plants throughout California.

Yellow scale, *Aonidiella citrina* (Coquillett), is similar to the California red scale, but its shield is yellowish in color. It is similarly a citrus pest but may be found occasionally on perennial greenhouse plants.

West Indian red scale (rufous scale), *Selenaspidus articulatus* (Morgan). Shield of the female resembles the Florida red scale, but is grayish brown or yellowish brown with the marginal portion distinctly lighter. It is regarded as a serious pest of citrus in tropical countries, and also infests a wide variety of ornamentals. Infestations have been found twice in California, on greenhouse crotons, and it was eradicated each time.

Mexican red scale, *Acutaspis albopicta* (Cockerell), resembles the Florida red scale, but the shield of the female is dark brown in color. It is rarely found in California on such plants as philodendron, and is eradicated whenever detected.

Rose scale, *Aulacaspis rosae* (Bouché), resembles the Boisduval scale, but the female shield has the nipple on one side. It is a common pest on rose and bramble stems, both outdoors and in greenhouses.

Cactus scale, *Diaspis echinocacti* (Bouché), closely resembles the Boisduval scale but is found only on various cacti. It is a common pest in California, both in the greenhouses and outside.

Mining scale, *Howardia biclavis* (Comstock). Shield of the female is whitish, circular, convex, with terminal nipple. It has the habit of burrowing beneath the outer bark, so that it is usually recognized by the nodular stem swellings on older wood and roots. It is a species which occurs on various tropical plants and has been found in several localities in California.

Cycad scale, *Furcadiaspis zamiae* (Morgan). Shield of the female is circular, slightly convex, with marginal nipple, and with outer ring cottony white. It occurs on the leaves of various cycads and is frequently found in California.

Lesser snow scale, *Pinnaspis strachani* (Cooley), is very similar to the aspidistra scale, but the shield of the female is white. This species has been found in California several times, particularly on sansevieria, ferns, and cycads. It is eradicated when detected.

Purple scale, *Lepidosaphes beckii* (Newman). Shield of the female is oystershell-shaped, elongate and generally curved, purplish or brownish in color. Shield of the male is similar but smaller and more elongate. Although primarily a pest of citrus, it is occasionally found on various ornamentals in greenhouses and outside.

Cymbidium scale, *Lepidosaphes machili* (Maskell), closely resembles other oystershell scales, but is found only on cymbidium orchids. Severe infestations are occasionally found in California greenhouses.

Mackie scale, *Lepidosaphes mackiana* McKenzie, closely resembles other oystershell scales, but is found beneath the sheath on stems of dendrobium orchids. It has been found several times in southern California greenhouses.

Noxious scale, *Lepidosaphes noxia* McKenzie, closely resembles the Mackie scale and also occurs only on dendrobium orchids. One infestation has been found in a northern California greenhouse.

Croton scale, *Lepidosaphes tokionis* (Kuwana), closely resembles the other oystershell scales, but occurs only on croton. It has been found twice in northern California greenhouses.

Proteus scale (sansevieria scale), *Parlatoria proteus* (Curtis). Shield of the female is elongate-oval, somewhat convex, thin and delicate, with nipple terminal and middle ring very large. Shield of the male is similar but smaller and more elongate. Occasionally it is found in California greenhouses on such hosts as sansevieria, various orchids, and palms. Eradication measures are taken when it is found.

Chaff scale, *Parlatoria pergandei* Comstock, is similar in appearance to the proteus scale, but

Fig. 38. The cactus scale: subcircular females and smaller, elongate males.

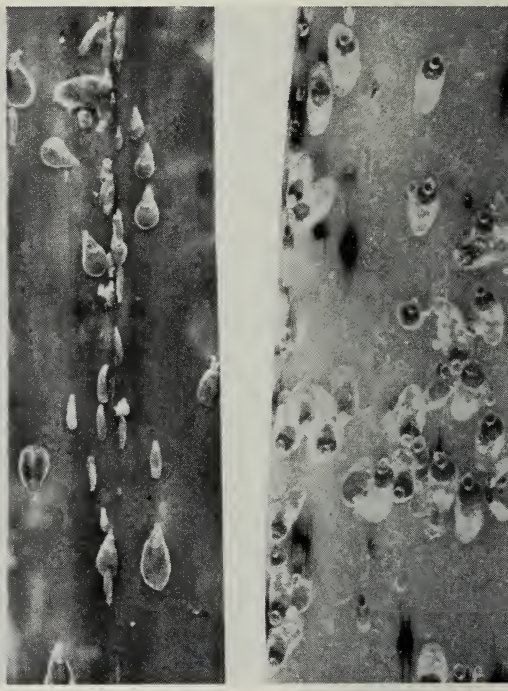


Fig. 39. Left, the cymbidium scale on cymbidium orchid; right, the proteus scale on vanda orchid.

the shield of the female is thick and the middle ring is smaller. Primarily it is a pest of citrus, but is occasionally taken on various ornamentals both in greenhouses and outside.

False parlatoria scale, *Pseudoparlatoria parlatorioides* (Comstock). Shield of the female is semitransparent yellowish, more or less circular, with nipple marginal. Shield of the male is similar, but smaller and oval. Occasionally it is found in California greenhouses, particularly on phoenix palms and cypripedium orchids. Eradication measures are taken whenever it is found.

Palm fiorinia scale, *Fiorinia fioriniae* (Targioni). Shield of the female is elliptical, thin, yellowish or brownish, with nipple terminal and remainder of shield formed by second skin which bears a longitudinal ridge. Shield of the male is white and felted. It is found occasionally in California greenhouses, especially favoring palms.

CONTROL

Control of armored scales is often very difficult because of the protection afforded by the shield over the body.

1. Light-oil emulsion: may give control where it can be used. Applied most effectively when crawlers are active. (See page 56.)

2. Calcium cyanide fumigation: gives very good control for most species, but the California red scale may be resistant. (See page 51.)

3. DDT: sprays have given effective control of crawlers of some species and have been used extensively against the Boisduval scale. It is necessary to maintain a residual on the plants until older scales have died, so applications are repeated every 3 or 4 months. (See page 52.)

4. Parathion: excellent control of many species, although mature forms may not appear dead for several weeks after application. (See page 57.)

PLUME MOTHS

Importance: The caterpillars of several species of plume moths cause damage of economic importance in California. Although they may chew on any part of the plant, the most noticeable injury is to the developing flowers.

Appearance: The caterpillars are yellowish, greenish, or purplish, with a black head, about 1 inch long when grown.

Adult moths are small, tan, with a wing expanse of about 1 inch. The wings are very slender and are held outstretched when at rest. Actually each wing is subdivided so as to resemble a series of plumes.

Development: Each female lays one hundred to two hundred eggs individually underneath the leaves. They hatch in 1 or 2 weeks, and the young caterpillars mine into tender buds or leaves. As they grow, they burrow into the stems or feed among terminal leaves and developing flowers. They mature in 1 or 2 months. The transformation stage is formed where they have been feeding, and this stage lasts 3 or 4 weeks. Adult moths are from several days to a week old before they start laying eggs.

Fig. 40. A fiorinia scale on podocarpus leaf.

Fig. 41. The snapdragon plume moth.

Species Found In California Greenhouses

Snapdragon plume moth, *Platyptilia antirrhina* Lange, often is a serious pest of snapdragons in southern and central California.

Geranium plume moth, *Platyptilia pica* Walsingham, is similar to snapdragon plume moth, but particularly prevalent on geranium in the coastal region of southern California.

CONTROL

Information concerning the use of newer insecticides is not available for the plume moths. Nicotine sulfate, rotenone, lead arsenate, and cryolite have not given adequate control. A pyrethrum and medium-oil spray has given control of exposed caterpillars and adults.

LOOPERS

Importance: Loopers, or measuring worms, are familiar caterpillars which eat the leaves of a wide variety of ornamental shrubs and trees. Only one species is of economic importance in California greenhouses.

Appearance: The caterpillars may be recognized by the series of looping movements which they make when they crawl. They frequently rest by holding on with the hind legs and straightening the body out. The caterpillars are variously colored, about 3/4 inch long when grown.

The moths have a slender body and broad, rather delicate wings. The wings are about 1 inch long and are held partly outstretched when at rest.

Development: Eggs are usually laid in small clusters on the foliage. As the caterpillars grow up, large portions of the leaves are consumed. They often fasten leaves together in which to hide during the day, and pass the transformation stage within such a shelter. There are several generations a year.

Species Found In California Greenhouses

Omnivorous looper, *Sabulodes caberata* Guenée. Caterpillars usually are yellowish or orange with narrow, green and black stripes. The moth is pale tan in color. The caterpillars

Fig. 42. Injury to snapdragons by caterpillars of the snapdragon plume moth.

are general feeders, attacking a wide variety of ornamental plants outdoors. They often invade greenhouses, particularly during the fall when they are most abundant.

CONTROL

1. DDT: effective control. (See page 52.)

LEAF BLOTCH MINERS

Importance: The leaf blotch miners are small caterpillars which usually feed within or curl the leaves of various ornamental shrubs and trees. Injured portions die. Only one species has been found in California greenhouses, but it often causes considerable trouble.

Appearance: The caterpillars are pale, about 1/2 inch long when grown. They are generally recognized by the characteristic blotches which they make in leaves when they are young, together with their pellets of frass.

Adults are small, slender moths, about 1/3 inch long. At rest, the wings are folded along the sides, and the front end of the body is held up high.

Development: Eggs are laid on the foliage. The newly emerged caterpillars

mine within the leaf tissues, forming an irregular blotch. As they mature, they emerge, curl over a portion of the leaf with silken threads, and feed on the inner surface. The transformation stage is formed where they have been feeding.

Important Greenhouse Species

Azalea leaf miner, *Gracilaria azaleella* Brants. Adults are prettily marked with bright purple and yellow. The caterpillars commonly infest greenhouse azaleas, but they do not appear to build up under lath house or garden conditions.

CONTROL

Both lead arsenate and nicotine or other plant product preparations are reported to give effective control. Certain of the newer insecticides appear to be preferable, however.

1. DDT: excellent control. (See page 52.)
2. Parathion: excellent control. (See page 57.)

LEAF TIERS

Importance: The leaf tiers belong to a group of caterpillars which are often important feeders on plants. Only one species, however, is found ordinarily in greenhouses.

Appearance: The caterpillars are pale in color, about 3/4 inch long when grown. They are generally found within leaves which are folded over or tied together for protection.

The moths are somber colored, about 1/2 inch long when at rest. The wings are held along the sides to give a triangular appearance.

Development: Eggs are laid singly or in small groups on the underside of leaves. They hatch in 1 or 2 weeks. The caterpillars feed almost entirely on the underside of leaves, chewing off the surface in irregular patches when they are young and eating holes when they are larger. The larval stage lasts about three weeks. The transformation stage occurs

Fig. 43. Azalea leaves showing damage by the azalea leaf miner.

in a slight cocoon among the foliage, and this stage lasts about three weeks. Multiplication is continuous in greenhouses, the generations overlapping.

Species Found In California Greenhouses

Greenhouse leaf tier (celery leaf tier), *Phlyctaenia rubigalis* (Guenée). The caterpillar is yellowish with a narrow green stripe down the back and a broader greenish stripe along each side. The wings of the moth are crossed with narrow, wavy, dark lines. This species is a common outdoor pest on garden crops and ornamental plants. It readily invades greenhouses to feed on a wide variety of crops.

CONTROL

Control measures which are employed for the omnivorous looper are also used for the greenhouse leaf tier.

LEAF ROLLERS

Importance: The leaf rollers are a very destructive group of caterpillars. They not only tie together and feed on the terminal leaves but they often bore into flower buds and terminal shoots. They are very persistent pests when they become established in greenhouses.

Appearance: The caterpillars are yellowish or pale greenish with a yellowish to black head. They are about 1/2 inch long when mature. When disturbed they wriggle violently, escaping backwards into their shelter or dropping by a silken thread.

Adults are more or less tan in color, the wings having an oblique, dark band across the middle and usually a spot beyond this on the front margin. They are

Fig. 44. Terminal growth of carnation showing injury by the carnation leaf roller.

about 3/8 inch long when at rest, the wings being folded along the back to give a bell-shaped appearance.

Development: Eggs are laid in overlapping masses on the leaves, and they hatch in 1 to 3 weeks. The caterpillars curl leaves over or web them together for protection, or else burrow into buds or tender shoots. Feeding continues for 3 or 4 weeks. A transformation stage is then formed in the leaf rolls or buds. Adult moths emerge in another 2 weeks, and the adult female may lay several hundred eggs. There may be from 1 to 5 generations annually, depending on the species.

Important Greenhouse Species

Orange tortrix, *Argyrotaenia citrana* (Fernald). Hind wings of the moth are white in color. It is a very common pest of fruit trees, berries, and many ornamental plants. Rose is a favorite host.

Carnation leaf roller, *Platynota stultana* Walsingham. The moth has very long palps projecting in front to resemble a long snout. It is a very serious pest of carnations, but other flowering plants are sometimes attacked.

Other Species Found In California Greenhouses

Apple skinworm, *Argyrotaenia franciscana* (Walsingham). The moth has hind wings gray in color. This species is of particular importance in northern California, infesting a wide variety of flowering plants.

Cyclamen leaf roller, *Clepsis buskana* Keifer. Front wings of the moth are golden in color. The overwintering caterpillars which mature in the early spring cause the most damage. It is occasionally found in greenhouses, particularly on cyclamen in northern California.

Oblique-banded leaf roller, *Choristoneura rosaceana* (Harris). The caterpillar is larger than the other leaf rollers. The moth has three oblique bands on front wing. It is a troublesome pest of flowering plants in many parts of the United States, and it readily adapts itself to greenhouse conditions. It is seldom found in California.

CONTROL

The leaf rollers are difficult to control, particularly because of protection afforded by the buds in which many of the caterpillars live. DDT is not effective against many species.

1. Cryolite: considerable control. (See page 54.)

2. Pyrethrum dusts: reported to be effective when a second application is made after a 30-minute interval. The first application serves to drive the caterpillars from concealment. (See page 59.)

3. DDD: effective control. (See page 52.)

4. Parathion: effective control. (See page 57.)

CUTWORMS

Importance: Cutworms, and armyworms, are destructive caterpillars which feed on many agricultural ornamental crops. Younger plants are often killed overnight by being cut off at the base, or, in other cases, the foliage may be eaten so extensively that they are ruined. They often eat into buds.

Appearance: Cutworms are shining, fat caterpillars, about 1 or 2 inches long when mature. They are gray, brown, greenish or yellowish, with darker markings. They hide in the daytime, usually in the ground, and come out at night to feed.

The adults are medium-sized, stocky, and somber-colored moths. They are commonly seen around lights at night. When at rest, the wings are folded over the body to give the insect a triangular outline.

Development: The eggs are laid singly or in clusters on the foliage, and they hatch in about one week. The caterpillars feed for 3 or 4 weeks. The transformation stage is usually in a cell in the soil, and it lasts for 2 or 3 weeks. The adult female lays several hundred eggs. There are several generations a year as a rule.

Important Greenhouse Species

Variegated cutworm, *Peridroma margaritosa* (Haworth). Caterpillar is gray or brown with darker markings and with a row of yellow dots down the middle of the back. It is a common pest throughout

California, often entering greenhouses to feed on young gardenias, carnations, and many other flowering plants.

Other Species Found In California Greenhouses

Tobacco budworm, *Heliothis virescens* (Fabricius). The caterpillar is greenish with longitudinal pale stripes. This is a common pest of geranium and pelargonium in southern California. Caterpillars feed on the buds and unfolded leaves so that they are ragged as they expand.

Corn earworm, *Heliothis obsoleta* (Fabricius). The caterpillar is light green to dark brown with light and dark longitudinal stripes. It is a common vegetable pest which occasionally becomes established in greenhouses, feeding on various flowering plants.

Beet armyworm, *Laphygma exigua* Hübner. Caterpillars vary from green to having black and white stripes along the back and sides. A periodic pest of truck crops, it has been noted feeding on greenhouse cinerarias in northern California.

Fern cutworm, *Euplexia lucipara* (Linnaeus). Caterpillars are green, matching the color of the ferns on which they feed. A European species which occurs rarely in California.

CONTROL

Although cutworms have been satisfactorily controlled with poison baits (see page 66) in the past, certain of the newer organic insecticides are better for greenhouse use.

1. DDT: excellent control. (See page 52.)

WEEVILS

Importance: There are a large number of species of weevils, and many of these are serious pests to plants. The adults commonly chew on the foliage or flowers, and the grubs generally eat on the roots or else feed in the stems, buds, or fruits.

Appearance: The grubs are fleshy, strongly arched, and sluggish. They are pale colored with a distinct head. The size varies considerably according to the species but commonly ranges from about 1/12 to 1/2 inch in length.

Adult weevils are hard-shelled insects which have the front portion of the head more or less prolonged to form a snout.

Fig. 45. Grub and adult of the black vine weevil.

They are often dark in color, and are commonly from 1/12 to 1/2 inch in length.

Development: Eggs may be dropped on the soil or laid on the plants. The grubs feed on the plant tissues and when mature enter a transformation stage in a cell in the soil or within the plant where they have been feeding. The adult weevils may live a considerable length of time as they continue to feed at night over the plants. The biology varies considerably according to the species.

Important Greenhouse Species

Fuller rose weevil, *Pantomorus godmani* (Crotch). Adults are grayish with an oblique, whitish line on each wing cover. They are moderately large, and with the snout short and broad. They are commonly found hiding in the foliage in the daytime, and they chew on the leaves at night. The eggs are laid in elongate masses near the tips of branches or near the base of the plant, and the grubs feed on the rootlets. This common species is particularly destructive to gardenias and roses, although a wide variety of plants may be attacked, either in greenhouses or outdoors.

Black vine weevil, *Brachyrhinus sulcatus* (Fabricius). Adults are brownish with golden flecks on the wing covers, otherwise similar in general appearance to the Fuller rose weevil. Adults hide in debris on the ground, coming out at night to scallop the leaves in a characteristic fashion. The eggs are dropped on the soil, ordinarily in the summer, and they hatch

in about two weeks. Young grubs feed on the tender rootlets, but as they become larger, in the winter or early spring, they may girdle the crowns of smaller plants. The transformation stage is passed in a cell in the ground. The adults emerge in the spring, and they may live for two years, laying several hundred eggs.

A very wide variety of plants are attacked, although azaleas and camellias are killed the most often. Infestations in greenhouses are usually initiated by bringing in infested soil, but invasion may result from the slowly crawling adults. Several other species of *Brachyrhinus* have been introduced into California, but they have not been found yet in greenhouses.

Other Species Found In California Greenhouses

Vegetable weevil, *Listroderes obliquus* Klug. Adult is moderate sized and brownish; each wing cover has an oblique pale marking and a tubercle near the back end; the snout is short and broad. The grubs are greenish. Both the adults and grubs feed on the foliage, and the grubs also feed on the roots. Eggs are laid mostly in the fall, and damage is found mostly during the winter and spring. Although principally a pest of vegetables, it is occasionally found in greenhouses feeding on various plants such as cyclamen in seedling flats.

Fig. 46. The cattleya weevil feeding on bud of cattleya orchid.

Orchid weevil, *Diorymerellus laevimargo* Champion, is small, shiny black, with a long, curved snout. The adults feed on the flower buds, petals, and young leaves at night and hide in the daytime at the leaf bases or in the potting material. The grubs feed inside the new roots, causing them to blacken and die. Formerly it was a very common and very destructive pest of cattleya and dendrobium orchids in California.

Cattleya weevil, *Cholus cattleyae* Champion, is large and black with conspicuous, white markings on the wing covers, and with a long snout. It is a South American immigrant which is seldom found in California. When present, however, it causes serious damage to cattleya orchids, both by the adult feeding punctures in the pseudobulbs and the larval feeding within the pseudobulbs, stems, or leaves.

CONTROL

The most satisfactory control of weevils is obtained with certain of the newer organic insecticides, although proprietary poison apple baits have been widely used for adults of the black vine weevil. For control of ground-inhabiting grubs, the insecticide usually must be mixed with the soil.

1. DDT: effective control. (See page 52.)

2. Benzene hexachloride: effective control of adults or grubs. (See page 50.)

FUNGUS GNATS

Importance: Fungus gnats are common greenhouse inhabitants, often occurring in such large numbers as to be a nuisance. The maggots ordinarily feed among decaying organic material in the soil. As a general rule they are not considered to be of economic importance, but there are a number of instances in which larval injury to roots of greenhouse plants has been reported in other parts of the United States.

Appearance: The young are slender, legless maggots which are white with a

black head. When mature they are about 1/4 inch long.

The adults are slender, blackish gnats, about 1/8 inch long. They run rapidly over the foliage, soil, and windows.

Development: Eggs are laid in the soil. Hatching takes place in about one week, and the maggots feed for about two weeks. A transformation stage is then passed in the soil which lasts about 1 week. Each female lays about 100 eggs.

CONTROL

Fungus gnats are effectively controlled with certain of the newer organic compounds.

1. DDT: effective for adults. (See page 52.)

2. Chlordane: excellent control of maggots and adults. (See page 51.)

3. Benzene hexachloride: effective for maggots and adults. (See page 50.)

GALL MIDGES

Importance: Gall midges comprise a large group which contains a number of important pests of ornamental plants. They generally make characteristic galls on the foliage or deform the buds and flowers. Several species, such as the rose midges, violet midges, and orchid midges, are important greenhouse pests in other parts of the country, but these have not been observed in California. The chrysanthemum gall midge, however, is a common and persistent pest.

Some species of gall midges are fungus feeders, and those belonging to the genus *Mycophila* in particular, have been observed in numbers in greenhouses, breeding among flower pots. These do no damage. Other species are beneficial, the larvae preying on destructive midges, mites, aphids, mealybugs and other scale insects. Several of these have been observed in California greenhouses.

Fig. 47. Galls of the chrysanthemum gall midge on chrysanthemum leaves.

Appearance: The larvae are small, fleshy maggots, without a head, and often yellowish or orange in color. They are commonly about 1/12 inch in length.

The adults are very delicate midges, usually reddish in color, and less than 1/12 inch in length.

Development: Eggs of gall-making species are laid on the new growth. The galls develop around the maggots as they feed. The transformation stage is usually found in the gall. The adult midges live only a day or so. The period from egg to adult is about one month in the case of the chrysanthemum gall midge, and the adult female may lay as many as 100 eggs.

Important Greenhouse Species

Chrysanthemum gall midge, *Diarthronomyia chrysanthemi* Ahlberg. Individual cone-shaped galls are formed on the leaves and stems. These may be so abundant that the leaves are deformed and the stems gnarled and misshapen. Only chrysanthemums are attacked, although some varieties are more susceptible to injury than others. It is a common greenhouse pest, although outside infestations also occur along the coast.

CONTROL

Until recently the chrysanthemum gall midge has been very difficult to control. Certain of the newer insecticides, however, are very effective.

1. DDT: adult control. (See page 52.)
2. Benzene hexachloride: excellent control of adults and immature stages within the galls. (See page 50.)

BULB FLIES

Importance: The maggots of several species of bulb flies are found commonly in association with bulbs of all types. One of these species is of considerable importance in destroying bulbs. Certain others may be secondary, the maggots preferring to feed on diseased or infested rootstocks. Bulb flies are primarily pests under field conditions, but infested bulbs are transferred to greenhouses.

Appearance: Bulb fly maggots are fleshy, whitish or dirty gray, without legs or a head but with a short, brown tube at the back end. They are from 1/2 to 3/4 inch long when mature.

Adults are medium-sized flies, about 1/3 or 1/2 inch long, dark in color with pale markings or hairs.

Development: Eggs are laid at or near the bases of plants or on exposed bulbs, and the maggots work into the bulbs. The transformation stage is passed in a brown case in the bulb or in the nearby soil. Adults are most active on warm, sunny days.

Important Greenhouse Species

Narcissus bulb fly, *Lampetia equestris* (Fabricius). The maggot is large, working in the center of the bulb and usually only one in each bulb. Adult is large and stocky, the body densely covered with hairs which are yellowish except for a variable black band which is often present across the middle. It is a common pest, and a wide variety of bulbs are subject to attack.

Other Species Found In California Greenhouses

Lesser bulb fly, *Citibaena tuberculata* (Rondani). These maggots are smaller than those of the narcissus bulb fly, and a large number are

Fig. 48. Maggot of the narcissus bulb fly working in the center of a bulb.

usually present in an individual bulb. Adults are slender, blackish green with pale markings. Although this species is very common on decaying bulbs, it would appear that primary injury is not generally caused.

Least bulb fly, *Citibaena narcissi* (Smith), is very similar to the lesser bulb fly and sometimes found in association with that species. Its occurrence is more limited, however.

CONTROL

Many bulb treatments have been tried with moderate success. These include fumigation with paradichlorobenzene, carbon disulfide, mercuric chloride, and calcium cyanide. Certain of the newer insecticides might be effective for bulb fly control, but information on their use is not available.

1. Methyl bromide: very effective bulb treatment. (See page 55.)
2. Hot water or vapor-heat treatment: effective for control of bulb infestations. (See page 46.)
3. Chlordane: reported to be effective for prevention of infestation of planted bulbs. (See page 51.)

LEAF MINERS

Importance: The maggots of leaf miners are found commonly tunneling within the leaves and stems of a wide variety of plants. The foliage is rendered unsightly by the larval mines and by the feeding punctures of adults. In the case of heavy infestations leaf drop follows.

Appearance: The larvae are soft, white maggots, with black mouth hooks. They are about 1/10 inch long when mature. Their tunnels are long and winding or else blotch-like.

The adult flies are stocky, about 1/12 inch long, and are blackish, sometimes marked with yellow. They are very active, flying among the plants and walking over the foliage.

Development: Eggs are deposited in small feeding holes made by the adults in the leaf tissues. Hatching takes place in 5 or 6 days, and the maggots feed in the leaves for about two weeks. The transformation stage is formed in the mine or in the ground, and it lasts about two weeks. The adults may live for 2 or 3 weeks, each female laying about 100 eggs.

Important Greenhouse Species

Chrysanthemum leaf miner, *Phytomyza atricornis* Meigen. Larvae make conspicuous, serpentine mines in the leaves, and the case of the transformation stage is whitish and occurs within the mine. The adult is uniform blackish. A wide variety of composite plants serve as hosts, chrysanthemum, cineraria, and marguerite being favorites. Although primarily a greenhouse pest in other parts of the United States, it is common both under glass or outside in California.

Other Species Found In California Greenhouses

Serpentine leaf miner, *Liriomyza subpusilla* (Frost). Larvae make narrow, twisting mines in the leaves, but the case of the transformation stage is brown and occurs in the soil. The adult fly is blackish with conspicuous yellow markings. It is a very common outdoor pest on many

Fig. 49. Tunnels of the chrysanthemum leaf miner in a cineraria leaf.

field crops and frequently enters greenhouses to attack a wide variety of plants.

Burdock leaf miner, *Dizygomyza maculosa* (Malloch). The larvae form irregular blotch mines, the transformation stage occurring in the ground. The adult fly is comparatively large, and uniformly black. Burdock, chrysanthemum, and various composites are commonly attacked outdoors, and occasional greenhouse infestations are found.

CONTROL

Until recently the leaf miners have been very difficult to control, because of the protection afforded the maggots within their mines.

1. Chlordane: effective control. (See page 51.)
2. Benzene hexachloride: effective control. (See page 50.)

SAWFLIES

Importance: Sawflies constitute a rather large group of insects, the immature stages of which feed on leaves or bore in stems. Several species are pests of ornamental plants, and two of these have been found in California greenhouses. The bristly rose slug is another common species in the state, but it has been found only outdoors.

Appearance: The larval stage of sawflies often resembles a caterpillar very closely, but a pair of fleshy legs are found on the first segment behind the three pairs of true legs at the front end of the body. They are commonly about 1/2 inch long when mature, and some species are prettily colored.

The adult sawflies are wasp-like insects but do not have a narrow waist. They are often black or marked with yellow or orange and about 1/2 inch in length.

Development: Eggs are laid in punctures within the plant tissues, and they hatch in about two weeks. The larvae feed on the plants for about one month, usually either skeletonizing leaves or eating the margins, or else mining in the stems. The mature larva makes a cocoon, usually within the stalk of a pithy plant, and many months may pass before the transformation stage is formed and the adults emerge. There is usually but a single generation annually, but some species have two generations each year.

Species Found In California Greenhouses

Western rose stem sawfly, *Hartigia cressoni* (Kirby). A pest of roses and brambles, the whitish larvae boring within the pith of terminal shoots. A common outdoor pest which frequently invades rose greenhouses and kills the terminal growth.

Violet sawfly, *Ametastegia pallipes* (Spinola). Larvae dark greenish with small white spots. They occur only on pansies and violets and are found infrequently in greenhouses. The young larvae feed on the underside of leaves making small holes, but as they become larger they rest in the daytime and come out at night to devour the margins.

CONTROL

Sawfly larvae are easy to control when they are exposed on leaves by use of the insecticides listed below. When they bore within the stems, however, it is necessary to cut off and burn the shoots as soon as the injury is discovered.

1. Basic lead arsenate. (See page 48.)
2. Cryolite. (See page 54.)
3. Parathion. (See page 57.)

STEM WASPS

Importance: The stem wasps comprise a group of tiny wasps. The larvae of a number of species are found in the stems of plants, often forming galls, or else infesting seeds. Certain species, however, are parasitic on other insects. Only one species is a pest to greenhouse plants, and it is restricted to orchids.

Appearance: The larvae are white, fleshy, without legs or a distinct head. They are about 1/6 inch long when grown.

The adult is a slender, black wasp, with clear wings, and it is about 1/7 inch in length.

Development: Individual eggs are inserted into the plant tissue, and the larvae burrow out cavities, causing the infested parts to become darkened and swollen. The transformation stage occurs within the burrow, and the life cycle is completed in about two months.

Species Found In California Greenhouses

Cattleyafly, *Eurytoma orchidearum* (Westwood), occurs within the small flower buds or pseudobulbs of cattleya orchids. Infested buds never bloom. An important pest of these plants which often has been encountered in California.

CONTROL

The cattleyafly has ceased to be a problem in orchid houses that have been sprayed three or four times annually with DDT. Prior to the use of this material, the infested parts were removed and burned, and repeated fumigations for extended periods were directed against the adults.

ANTS

Importance: Ants are of particular importance to the grower of ornamental plants, because many species are fond of the honeydew excreted by aphids, mealybugs, and soft scales. They may tend and pasture these pests and guard them from their enemies. Infestation of the honeydew-excreting insects may originate or spread by ants moving them from plant to plant. Sweet plant exudates such as secreted by many orchids, are also attractive to ants. Certain species may be of importance in directly attacking plants.

Appearance: Ants are wasp-like insects, having a narrow waist. They are reddish, brown, or black in color. The forms most commonly seen are the workers which are wingless and usually about 1/10 to 1/5 inch in length.

Development: Ants are social insects which live in colonies. Their nests are often simple and located either in the ground outside or in greenhouse beds and potting material. The eggs and worm-like larvae are found in the nests where they are cared for by the workers. At mating time swarms of winged males and females come out to start new colonies.

Important Greenhouse Species

Argentine ant, *Iridomyrmex humilis* Mayr is a small, brown ant which follows definite trails. The workers are fond of sweets and readily enter greenhouses for honeydew. It has become a widespread and serious pest since its introduction into California.

Other Species Found In California Greenhouses

California fire ant, *Solenopsis xyloni maniosa* Wheeler, is yellowish red with a black abdomen. It feeds upon greenhouse plants, steals seeds, and tends honeydew-excreting insects.

California honey ant, *Prenolepis imparis californica* Wheeler, is shining brownish black. The abdomen is greatly distended after feeding. It is commonly found throughout the state and often enters greenhouses to feed on honeydew and plant exudates.

California brown field ant, *Formica cinerea* Mayr, is a brown, medium-sized species. It frequently invades greenhouses to tend honeydew-excreting insects.

Western pavement ant, *Tetramorium pacificum* Mayr, is a large, red ant. It has been found frequently in orchid houses.

CONTROL

The use of liquid ant baits containing sodium arsenite is being replaced by one of the newer organic compounds which may give control for many months as a result of a single application.

1. Chlordane: excellent control with applications to lower walls of greenhouse and sides and supports of benches. (See page 51.)

MILLIPEDES

Importance: Millipedes are found commonly in damp soil or leaf mold where they feed on decaying organic material. Several species, however, are known to feed occasionally on sprouting seeds or roots.

Appearance: Millipedes are long, worm-like animals that are related to centipedes but differ in having two pairs of legs on each segment. Their bodies are hardened, dark colored, about 1/2 to 1 inch in length. They coil in a characteristic manner and are active only at night.

Development: Eggs are laid in large clusters in the soil, and they hatch in

about three weeks. The young grow gradually in size, adding segments and legs until mature. There is one generation each year.

Important Greenhouse Species

Greenhouse millipede, *Orthomorpha gracilis* Koch, is brown with pale sides. It is a common greenhouse inhabitant although it also occurs outdoors in California. A variety of flowering plants have been reported to be injured.

Other Species Found In California Greenhouses

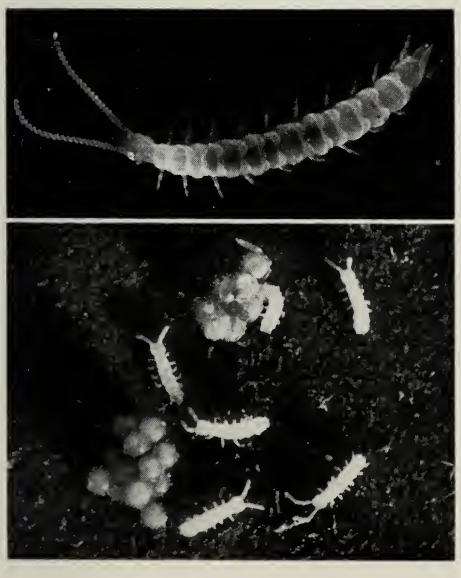
Common millipede, *Diploiulus luscus* (Meinert), is small and brown. It is a common species outdoors in California and occasionally found in greenhouses. It has been reported to be injurious to begonia tubers.

Bulb millipede, *Nopoiulus minutus* (Brandt), is brownish with a row of black spots on each side. It is found eating into bulbs occasionally.

CONTROL

Millipedes are very easily controlled with certain of the newer organic preparations.

1. DDT. (See page 52.)
2. Chlordane. (See page 51.)
3. Benzene hexachloride. (See page 50.)
4. Parathion. (See page 57.)



GARDEN CENTIPEDES

Importance: Garden centipedes occur in damp, loose soil or ground debris. Most of the species feed on algae and fungi, but one species eats the tender roots of plants. It is often a serious pest in greenhouses.

Appearance: Garden centipedes are soft, white, and elongate, about 1/2 inch long when grown. They bear one pair of legs on each segment, the adults having twelve pairs.

Development: Eggs are laid in small batches, and they hatch in about two weeks. The young gradually increase in size and gain legs, and they mature in several months. Adults may live for several years, wandering at different levels in the soil from the surface to a depth of over four feet.

Important Greenhouse Species

Garden centipede, *Scutigerella immaculata* (Newport), has longer legs and is more active than related species. Damage is caused to various plants but particularly to bedding plants such as snapdragons under greenhouse conditions.

CONTROL

In view of the fact that the garden centipede occurs commonly at considerable depths in the soil, steam sterilization of earth beds does not effect control. A soil fumigant with considerable residual action is needed in such cases.

1. D-D or EDB: most satisfactory for soil fumigation before planting. (See pages 53 and 54.)
2. Benzene hexachloride: affords protection of established plants. (See page 50.)

Fig. 50. The garden centipede. Above, adult; below, eggs and young.

SLUGS and SNAILS

Importance: Slugs and snails are common greenhouse pests where the humidity is high. They often feed on the leaves, stems, or roots of various plants, scraping off the surface or making irregular holes.

Appearance: Snails and slugs are animals that are related to clams and oysters. Their bodies are soft, covered with slime, and they are commonly from 1/2 to 2 inches long. Snails form a hard shell into which they can retreat, while slugs do not have this protective covering. Both come out at night to feed and leave a characteristic trail of slime over the path.

Development: Eggs are laid in small masses, and under favorable conditions they hatch in about one month. Growth is slow and gradual, maturity being reached in from several months to two years.

Important Greenhouse Species

Greenhouse slug, *Milax gagates* (Müller), is black or dark gray with a longitudinal ridge down the back. It is a very destructive species and is commonly found in greenhouses and gardens.

Gray garden slug, *Agriolimax agrestis* (Linnaeus), is light grayish with scattered darker spots. It is a common garden pest which also is found commonly in greenhouses feeding on orchids and various other plants.

Other Species Found In California Greenhouses

European brown snail, *Helix aspersa* (Müller). The shell is large and brownish with spiral dark bands which are broken by light cross streaks. This snail is common throughout California and frequently found in greenhouses. A wide variety of low plants are attacked.

Bush snail, *Zonitoides arboreus* Say. The shell is small, brown, nearly flat. Common throughout the United States and sometimes found in California greenhouses on orchids and other plants.

Cellar snail, *Oxychilus cellularis* (Müller). The shell is medium sized, pale brownish or whitish, and nearly flat. This species is widely distributed on the Pacific Coast and occasionally is found in greenhouses.

Drapernald snail, *Oxychilus drapernaldi* (Beck), is similar to the cellar snail but somewhat larger. It is established in gardens and greenhouses in northern California.

CONTROL

None of the newer insecticide materials has been found to be effective for slug and snail control.

1. Metaldehyde and calcium arsenate bait: checks infestations. (See page 66.)

PILLBUGS and SOWBUGS

Importance: Pillbugs and sowbugs are common greenhouse inhabitants which usually feed on decaying organic material. In fact, they may devour the manure used for fertilizer. At times, however, they also feed on the tender shoots of young plants.

Appearance: Pillbugs and sowbugs are related to shrimp and crayfish and similarly breathe by gills. They are more or less gray, elliptical, about 1/2 inch in length. The back is covered by a series of plates, and seven pairs of legs are present. They are active at night, hiding in the soil and under flower pots in the daytime.

Development: The young hatch from eggs held in a pouch in the female, and they gradually increase in size, maturing in about one year. Damp greenhouse conditions favor their development.

Important Greenhouse Species

Greenhouse pillbug, *Armadillidium vulgare* (Latreille), rolls into a ball when disturbed. A common greenhouse and outdoor pest which has been introduced into California, it is particularly destructive to bedding plants such as asparagus fern.

Dooryard sowbug, *Porcellio laevis* Koch, runs into hiding when disturbed. It is found commonly in greenhouses and outdoors and has been reported to injure plants.

CONTROL

Pillbugs and sowbugs formerly were controlled with baits. Certain of the newer

insecticides are more satisfactory, however. They are applied to the surface of the soil, either as sprays or dusts.

1. DDT. (See page 52.)
2. Chlordane. (See page 51.)
3. Benzene hexachloride. (See page 50.)
4. Parathion. (See page 57.)

NEMATODES

Importance: Nematodes which infest plants are very destructive. They injure the plants by killing tissues or by producing abnormal growth. Several species are found occasionally in California greenhouses.

Appearance: Nematodes are round worms, without body segments. The ones which infest plants are very small, mature females being about 1/20 inch long. Exceedingly large numbers may be present. It is by their characteristic injury that the presence of nematodes is suspected.

Development: Eggs are laid where they feed, and the worms mature in from two to four weeks. Adult females may each lay several hundred eggs.

Species Found In California Greenhouses

Root-knot nematode, *Heterodera marioni* (Cornu), works in the roots, causing gall formations which interfere with the transportation system of the plant. Infested plants become stunted, sickly, and often die. Young larvae which wander through the soil are responsible for new attacks. A very wide variety of greenhouse plants are subject to infestation.

Foliar nematode, *Aphelenchoides olesistus* (Ritzema Bos), works in fleshy leaf tissues, producing irregular, blackened patches. Adults are able to wander over the surface of the plant in films of moisture, and they are capable of remaining dormant for some time. A number of greenhouse plants are subject to infestation, common ones being African violet and peperomia. Birds-nest fern is often infested by a similar form.

Bulb and stem nematode, *Ditylenchus dipsaci* (Kühn), works in bulbs, stems, or leaves, producing swellings, twisting, and stunted growth. The mature larvae may wander through the soil to infest new plants, and this stage may remain inactive for several years. There are distinct forms which are restricted to a given type of plant, but the host list is large.

Fig. 51. Symptoms of the foliar nematode on birds-nest fern.

CONTROL

Nematodes are serious pests and their control is difficult. Infested plants should be completely discarded.

1. Steam sterilization: effective for treatment of soil and pots. (See page 46.)
2. D-D or EDB: effective soil treatment. (See pages 53 and 54.)
3. Heat treatment: effective for control of bulb infestations. (See page 46.)

Methods of Control

BIOLOGICAL CONTROL

The insect pests occurring in greenhouses are likely to be isolated from the natural enemies which accomplish varying degrees of control under outdoor conditions. Biological control in greenhouses consists for the most part of artificially rearing and liberating certain of these enemies. The use of such predators and parasites is impractical when they are killed by insecticides which may be used for the control of other pests.

The ladybird beetle, *Cryptolaemus montrouzieri* Mulsant, is a voracious feeder on mealybugs in both larval and adult stages. This beetle was originally collected in Australia, and colonies were liberated in California citrus orchards many years ago. A number of growers have used them in gardenia ranges. Their results have been variable, but in general the mealybug populations have been considerably decreased but not eliminated. Conditions unfavorable for the development of the beetles may occur during the winter, and new liberations are then necessary in the spring.

The Sicilian parasite, *Leptomastidea abnormis* (Girault), also has been released to a limited extent in gardenia ranges for control of the citrus mealybug.

In other parts of the country parasitic wasps, *Encarsia formosa* Gahan, have been released in greenhouses infested with the greenhouse whitefly. Very satisfactory control has been reported.

Fig. 52. Larvae of a ladybird beetle which feeds on mealybugs.

HEAT TREATMENT

Steam Sterilization

Sterilization of the soil with steam is a well-known practice for the control of many pests. Many plant disease organisms and weed seeds also may be killed by steam, and conditions more favorable in general to plant growth may be produced.

The soil should be dry and loose at the time of steaming. The type and condition of the soil and the amount of steam available per unit area are important considerations for the length of time necessary for sterilization. From 2 to 10 hours may be required, and a soil temperature of 140° F to 150° F should be attained.

For the treatment of small quantities of soil for flats or potting purposes, various types of box sterilizers are used.

The inverted pan system and the buried pipe or tile system are used for steam applications to the beds.

Inverted Pan. In this system a rectangular galvanized-iron pan, 6 to 9 inches deep, is inverted over the soil, and steam

is admitted under pressure through connections in the pan. This method is fairly satisfactory, with killing temperatures being produced at depths of 5 to 10 inches.

Buried Pipe. The more efficient method of steam sterilization is the use of buried perforated pipes or tiles. The pipes are from 1¼ to 2 inches in diameter, perforated at 6- to 12-inch intervals with holes about ¼ inch in diameter. They are laid at a depth of 6 to 12 inches with spacings of 12- to 16-inch intervals. One end of each pipe is bent to protrude from the ground and is provided with a union to a crossheader which is connected with the steam pipe. Both 3- and 4-inch irrigation tile are used commonly in place of the pipe. The tile lines are buried from 12 to 18 inches deep and from 18 to 24 inches apart. Steam from a high-pressure boiler (80 or more pounds pressure) is admitted to the pipes or tile lines, while the soil is covered above with a tarpaulin.

Hot Water Sterilization

Hot water treatments of ground soil have not proved successful, but this method often has been used for the control of bulb pests, such as nematodes, mites, maggots, and aphids, and also for the control of the cyclamen mite.

Bulb treatment consists of submersion in water ranging in temperature from 110° to 111° F, for a period of 2½ to 3 hours. For the control of the cyclamen mite, the plant material is immersed for only 15 to 20 minutes.

The water should be agitated or circulated to insure a constant and uniform temperature after the plant material is submerged. Temperatures over 111.5° F are apt to result in plant injury.

Vapor-heat Treatment

The vapor-heat method of bulb treatment involves the use of a treating room equipped with a conditioning machine which circulates water-mist and air saturated with water vapor at the desired temperature. Similar to the hot water treatment, a temperature of 110° to 111° F is the most favorable. Periods of bulb exposure vary from ½ to 1½ hours for mite and fly control to 8 hours for nematode control. Bulbs intended for greenhouse flower production should be treated early in the fall, after at least three weeks of drying. For control of the cyclamen mite, the plant material is exposed for 30 to 60 minutes.

CHEMICAL CONTROL

There are three considerations which may be stressed with regard to the chemical control of greenhouse pests:

1. *Use the proper insecticide against the specific pest involved.* Practically all of the insecticides are specific against certain pests or groups of pests. The insect should be recognized, and the selection of an insecticide for its control should be based on a knowledge of its value against that insect, as well as the more obvious considerations of plant tolerance, ease of application, objectionable residue, relative danger to humans, and cost.

2. *The treatment should be thorough.* Wherever possible the pest should be eliminated, and this is more readily possible since recently developed materials have become available to augment the older insecticides.

3. *The grower should be alert to recognize incipient infestations and to employ timely treatment.* The problems of control are more easily solved before widespread destruction occurs and large numbers of pests are present. In this connection it is important to examine carefully and to decontaminate when necessary any new plant or other material before it is introduced into a greenhouse. This is the only source of infestation of a large number of greenhouse pests.

Many new insecticides have been appearing on the market since the war. The grower should learn to recognize these by the chemical name which is given on the label as the active ingredient.

The Insecticides

Insecticides are nearly always poisonous to humans, and the newer ones are released before their hazards are well understood. For this reason, the grower should handle the materials with great care. This is particularly true of concentrated forms of the insecticides.

The synthetic organic insecticides which have recently come on the market are continually undergoing change and improvement, with regard to both the technical material and the formulations. Other new insecticides are being evaluated, and some of these will become commercially available.

These materials are released before they are tested extensively on the extremely wide range of greenhouse plants, their numerous varieties, and under all the possible growing conditions. These insecticides, however, are often very valuable for pest control, and the grower should satisfy himself as to the tolerance of the particular plants to be treated.

Accuracy of dosage is essential with modern chemicals. Not only are accurate measures of the insecticides necessary to minimize the danger of plant injury, but they also are necessary to ensure effective control.

ARSENICALS

Lead Arsenates

Arsenicals containing lead have been used extensively for the control of leaf-chewing insects such as caterpillars and beetles. There are two types of such compounds, standard lead arsenate and basic lead arsenate.

Standard lead arsenate contains a higher percentage of arsenic than the basic type, and it is a stronger poison, acting more quickly. It is also more susceptible to the action of other chemicals, particularly those of an alkaline nature (such as soaps), and is more or less decomposed by them when used in the spray. The soluble arsenic so formed may lead to severe burning of tender foliage. Under moist greenhouse conditions, considerable foliage injury may result when standard lead arsenate is used alone.

Basic lead arsenate, although a weaker poison with slower action, is not appreciably decomposed by moisture or slightly alkaline materials. This type may be used with safety on most foliage. When applied as a spray, basic lead arsenate is used at the rate of 2½ to 5 pounds to 100 gallons of water.

In preparing a spray a thin paste should be made before final dilution. Pastes which are commercially available contain approximately half as much arsenic as the corresponding powders and should be used at twice the dosage. A spreader should be used with the lead arsenates, unless one has been added in the commercial formulation.

When combined with a carrier such as sulfur and used as a dust, lead arsenate is used at a rate of 10 per cent by weight.

Calcium Arsenate

Calcium arsenate is somewhat similar to the lead arsenates. It contains a rather high proportion of soluble arsenic, therefore it is not used as a spray. It also has a high lime content and so is incompatible with many insecticides. It has been used to some extent by floriculturists in cutworm baits, but chiefly in slug and snail baits. (See Metaldehyde, page 54.)

Paris Green

Paris green was formerly used extensively in greenhouses for the control of chewing insects because it is inconspicuous on green foliage. It contains, however, a high and variable content of water-soluble arsenic, and is therefore likely to cause burning.

As a spray, Paris green is mixed with twice its weight of hydrated lime to neutralize the soluble arsenic, and diluted at the rate of about 1 pound to 100 gallons of water. It has also been used in 5 to 10 per cent dusts. Paris green sometimes has been substituted for arsenic trioxide or sodium arsenite in baits, using about double the proportions given for the latter compounds.

Arsenic Trioxide

Arsenic trioxide or "white arsenic" has been used in baits for the control of pests such as cutworms, the black vine weevil, sowbugs, pillbugs, and millipedes. The basic formula is 1 pound of arsenic trioxide to 25 pounds of bran (2 teaspoons of arsenic trioxide to 1 pound of bran).

These ingredients are mixed dry and then sufficiently moistened to make a soft mash. Alfalfa meal, shorts, dried beet pulp, or rice meal may be substituted for the bran. Molasses, banana oil, or finely ground lemons or oranges are sometimes added in an effort to make the bait more attractive. The bait is scattered thinly over the soil and is applied in the evening for nocturnal pests.

Sodium Arsenite

Sodium arsenite is very soluble, and it is extremely poisonous to plants and animals. It is the poison which is most commonly employed in commercial ant baits and is sometimes used in other baits. Because it may be made by heating arsenic trioxide with washing soda (sodium carbonate) or lye (sodium hydroxide), it is sometimes called "arsenite of soda."

Caution. Baits containing sodium arsenite or other arsenicals should be handled with care and should not be placed within access of children and pets.

AZOBENZENE

During the past few years azobenzene fumigation has played an important role in the control of spider mites on gardenias, roses, and other crops. The mites, including the eggs, die over a period of several days to a week following treatment, and a single application generally gives from 95 to 99 per cent control.

Steam-pipe vaporization of 70 per cent azobenzene powder has been the general method of fumigation, although a 90 per cent powder is now available. The standard dosage with the 70 per cent material is 1 pound per 40,000 cubic feet of space. It is mixed with water to form a paste, painted onto the pipes throughout the house, and the steam is then turned on, first in one set of pipes and an hour or so later in the other set. Fumigation should be carried on under warm temperatures (70° to 95° F), preferably 75° F, and the house should remain closed for six hours before ventilating and slow cooling.

The pure azobenzene crystals may also be used for vaporization, either with hot plates, lamps, or steam-pipe boxes, and the standard dosage with this material is 1 pound to 57,000 cubic feet (2 ounces per 7,000 cubic feet), evaporated over a two- or three-hour period.

Azobenzene also is available in a powder form ("pressure fumigator") which is released with the smoke when the material is ignited in the can. This type of fumigation is convenient and is apt to produce less-injurious effects on the plants. One pound of this material is used for each 10,000 cubic feet. Slow-burning azobenzene candles also have been produced, and this chemical has been used to some extent as micronized dusts.

In general, azobenzene has a good record of foliage safety, although in some cases tipburn of young leaves and bleaching or dropping of mature leaves occurs. The greatest objection has been to the discoloration of red flowers. It is possible that azobenzene serves as a stimulant to plant growth. In addition to gardenias and roses, a number of other crops have been fumigated successfully, including carnations, chrysanthemums, and snapdragons.

BENZENE HEXACHLORIDE

Benzene hexachloride, commonly shortened to "BHC," is the generally accepted name for the chemical hexachlorocyclohexane, a recently developed insecticide which was first known as "666." Its insecticidal properties were discovered in France in 1941, independently in England in 1942, and commercial quantities were available in the United States in 1947.

Outstanding uses of the material appear to be for the control of such soil pests as the garden centipede, millipedes, sowbugs, springtails, wireworms, grubs, and for the control of gall midges, leaf miners and other maggots. It is effective for the control of many beetles, aphids, and thrips, as well as certain caterpillars and other insects.

Commercial preparations of benzene hexachloride are composed of various forms of this compound and also impurities. The form which is known as the "gamma isomer" is accepted to be the principal toxic ingredient, and insecticidal considerations are based on this form. Benzene hexachloride is insoluble in water, but soluble in certain organic solvents. The residue is effective for 1 or 2 weeks, and an insecticidal vapor is slowly released.

Commercial material has been available principally in two forms, dusts and wettable powders. Dusts containing from 0.5 to 4 per cent gamma isomer are spread on or worked into the soil. The rate of usage is 1 to 3 ounces of the 1 per cent gamma isomer per 100 square feet. The chemical may be dispersed over the foliage at the rate of 1 ounce of the 1 per cent material per 100 square feet.

Wettable powders containing approximately 6 to 12 per cent gamma isomer have been used the most widely. These are applied at the rate of 1 to 2 pounds of the 6 per cent gamma isomer, or ½ to 1 pound of the 12 per cent gamma isomer, per 100 gallons of water. These preparations possess a persistent and obnoxious odor.

More purified wettable powders, containing approximately 25 to 36 per cent gamma isomer, have been more recently available, and these are applied at the rate of about 1 pound per 100 gallons of water. Preparations containing this higher amount of gamma isomer are preferable for use with ornamentals, because the objectionable odor is considerably reduced and because isomers which are believed to be of greatest toxicity to plants are reduced.

Benzene hexachloride is available also as a liquefied-gas aerosol.

Because of the possibility of plant injury, caution should be followed in the use of benzene hexachloride. Considerable burning of stocks has resulted with heavier applications of dusts, and seedlings may be injured, or stunting may occur, when it is used excessively in the soil. Benzene hexachloride is one of the newer materials which has not been tested very extensively on ornamental plants, and the grower should treat only a small sample first to assure himself with regard to the tolerance of the crop to be treated.

Caution. Benzene hexachloride is poisonous to man. Care should be taken to avoid inhalation of the dust or spray. Liquefied-gas aerosols of this chemical should be applied only while wearing a gas mask with filter for organic vapors, and protective clothing should be worn.

CARBON DISULFIDE

Carbon disulfide is very toxic to plants, but it has been used to some extent on bare soil as a fumigant for the control of such pests as the garden centipede and soil mealybugs. It is a colorless, ill-smelling liquid which evaporates quickly when exposed to the air. It is heavier than air and penetrates downward into the soil.

Commercial preparations consist of a rather unstable emulsion which is diluted to from 0.25 to 0.5 per cent actual material (1 quart to 2 quarts actual carbon

disulfide per 100 gallons of water), and applied to the surface of the soil at the rate of about 5 gallons per square yard.

Caution. Carbon disulfide is poisonous and should be handled with care. The vapor is highly inflammable, and even hot steam pipes may ignite the gas.

CHLORDANE

Chlordane is a recently developed insecticide which is particularly effective for the control of ants. It also is promising for the control of leaf miners and other maggots, earwigs, certain caterpillars, and grubs.

The technical material contains several chlorinated hydrocarbons of which the form containing seven chlorine atoms is now believed to be the most toxic. Chlordane is an oily liquid, completely soluble in common organic solvents but insoluble in water. The residue slowly vaporizes, but a residual action persists for about one week. It is formulated as a dust, wettable powder, emulsion, or solution.

Dusts are generally used at 5 to 10 per cent strength, and at the rate of 1 ounce per 100 square feet. Wettable powders (containing 50 per cent chlordane) and emulsion concentrates (1 quart of concentrate containing 45 per cent actual material or approximately 1 pound chlordane) are used at the rate of from 1 to 2 pounds actual chlordane per 100 gallons water.

A 2 per cent oil solution also is available for ant control. In this form the material is applied only to the walls, walks, floors, and sides of the benches.

There appears to be considerable plant tolerance to the above concentrations, but comparatively little information is available with regard to the tolerance of greenhouse crops. For this reason the grower first should treat only a sample of plants to satisfy himself as to the tolerance of the crops needing treatment.

Caution. Chlordane is poisonous and care should be taken to avoid inhalation of the dust or spray.

CHLOROPICRIN

Chloropicrin is a poisonous tear gas which has been used to a limited extent as a soil fumigant for the garden centipede, nematodes, and certain other soil pests. It is a very heavy gas which penetrates downward, and it is relatively noninflammable.

Chloropicrin cannot be used at all with growing plants, and it will injure germination of certain kinds of seeds. Bare soil should be treated ten days before planting.

CYANIDE

Hydrogen cyanide is a very deadly gas which has been used for many years as a greenhouse fumigant for the control of aphids, thrips, whiteflies, and certain scale insects.

Liquefied hydrogen cyanide may be obtained in heavy steel cylinders from which the gas is liberated when the pressure is released. Sodium or potassium cyanide, when treated with sulfuric acid, quickly releases the gas, and the combination of these materials in earthen pots has been used for greenhouse fumigation. The use of calcium cyanide as a source of hydrogen cyanide gas is the easiest and the most generally accepted method for such fumigation.

Commercial calcium cyanide is a dark gray dust yielding up to about 50 per cent by weight of hydrogen cyanide. The action of moisture from the atmosphere readily liberates the gas from this material. From ¼ to 1 ounce per 1,000 cubic feet are the dosages in general use, and it is advisable to test the lighter amount first.

The proper amount of material is evenly scattered along the walks late in the evening (at dark), and the house is ventilated early the following morning (before sunrise). High humidity increases the risk of plant injury, so the house should not be watered from 12 to 24 hours preceding fumigation. The temperature should not fall during fumiga-

tion because of condensation on the foliage, and it should be within the range of 52° to 70° F.

Caution. Hydrogen cyanide is a deadly poison, and great care should be exercised to prevent inhalation of the gas. It is not safe to enter a house while fumigation is in progress nor until the house has been thoroughly ventilated.

DDT AND RELATED COMPOUNDS

DDT

DDT is the common name for the white, crystalline compound dichloro-diphenyl-trichloroethane. Technical grade preparations also contain closely related compounds which are less toxic to insects. In 1939, a Swiss firm reported this material to be an effective insecticide, and in 1943, it was first available in the United States for extensive experimental work. It has since become widely known, but there is much to be learned concerning its use on ornamentals.

DDT is highly effective for the control of many caterpillars, the grubs and adults of many beetles, thrips, adults of midges and many other flies, plant bugs, leafhoppers, crawlers of certain scale insects, ants, pillbugs, termites, and certain other pests of ornamental plants. It is not an ovicide but possesses insecticidal properties over a long period of time after application (up to three months under protected conditions), thus killing the immature forms as they hatch.

In some cases the use of DDT outdoors has appeared to cause an increase in the numbers of certain pests. A considerable increase of spider mites, certain aphids, and other insects has been observed.

Dust preparations containing from 1 to 10 per cent DDT are sometimes used in greenhouses and for soil treatment. One ounce of a 5% dust is used per 100 square feet. A longer residual action is obtained with the use of spray material, and most growers prefer such applications.

The wettable powder preparations are safer for spraying on plants inasmuch as there is no danger of plant injury by the solvent. In order to avoid unsightly residue the wettable powders containing high percentages of DDT (50 to 90 per cent) are desirable, and these are used at the rate of about 1 pound actual DDT per 100 gallons.

The emulsions of DDT are made with a large number of organic solvents. Some of these, like xylene solutions, are formulated primarily for spraying walls for fly or ant control. Emulsion concentrates (generally 25 per cent DDT) are diluted at the rate of about 1 pint per 100 gallons water for application to plants.

Certain plants, such as kalanchoe, are readily injured by DDT. Several varieties of camellias (particularly Cheerful and Everet R. Rust) and at least one variety of rose (Eclipse) are reported to be susceptible to considerable injury. It is possible that the accumulation of DDT in the soil over long periods of time may produce injurious effects on plants.

Caution. Care should be taken to avoid inhalation of DDT dust or mist, and absorption of the emulsion through the skin.

Methoxychlor

Methoxychlor is the name used in reference to methoxyphenyl- (or dianisyl-) trichloroethane. It is closely related to DDT, but is less effective against some insects and more effective against others. It is considerably less toxic than DDT to mammals. Advantages of methoxychlor for greenhouse use have not been determined.

DDD

DDD (or TDE) is a name used to refer to dichloro-diphenyl-dichloroethane. It is very similar to DDT, but is more toxic to certain insects and less toxic to other insects and to man. The advantages of DDD in controlling greenhouse insects have not been determined, except in the case of orange tortrix. To control this

pest DDD may be applied as a spray, using 2 pounds of 50 per cent wettable material to 100 gallons of water.

DICHLOROBENZENES

Paradichlorobenzene

Paradichlorobenzene is a white, crystalline compound which volatilizes at room temperatures. It has been used to some extent as a soil fumigant for the control of root aphids, grubs, and wireworms, but it must not be used on plants. At one time the crystals were sprinkled on orchid pots for the control of orchid weevils, but plant injury was later noted.

Orthodichlorobenzene

This compound is similar to paradichlorobenzene, but it is a liquid. It has been reported to give good control of mealybugs on phoenix palm roots, and it has also been used successfully for termite control. This material is also generally toxic to plants.

DICHLOROETHYL ETHER

There are two forms of dichloroethyl ether, of which the β-β' form is the most common commercially. It has a definite odor, and is irritating to the eyes, nose, and throat. The principal use of dichloroethyl ether has been as a soil fumigant where it has been used with some success for the control of soil mealybugs, root aphids, garden centipedes, wireworms, and maggots.

It is used as an emulsion which is diluted to from 0.3 to 0.5 per cent of actual material (1 pint to 1 quart of actual material to 100 gallons of water). The rate of application is such as to wet the soil down (about 3 gallons per square yard). Many plants may be injured by this treatment.

Dichloroethyl ether also has been used experimentally for greenhouse fumigation, the pure material being volatilized by an electric fan. Such fumigation is reported to be effective for aphids, spider mites, thrips, and adult whitefly, but foliage burning and flower bleaching are caused on many plants.

DICHLOROPROPANE-DICHLOROPROPENE

A mixture consisting mainly of dichloropropane and dichloropropene (1 part of the former to 2 parts of the latter) is commonly known as D-D. It has been developed recently as a soil fumigant which gives effective control of the garden centipede, wireworms, nematodes, and certain other soil insects and pathogens.

D-D is a dark liquid which is applied most effectively by means of a hand-type injector regulated to give an individual dosage of 3.5 ml. (cc.) at 12-inch spacings and 6 to 8 inches depth. The soil should be friable and moist.

D-D is not suitable for use with living plants, and the beds should not be planted for two to three weeks following treatment, or longer if a strong odor of the fumigant is detected in the soil.

Caution. D-D is poisonous and should be handled with care.

DIMETHYL CARBINOL

Di(p-chlorophenyl) methyl carbinol (DMC) is one of the new organic compounds which has shown some promise for mite control. It is reported to give considerable control of spider mites on deciduous fruit trees. It is effective against the false spider mites and shows some promise against the cyclamen mite.

DMC possesses considerable residual action. Emulsion concentrates (25% technical DMC) are available, and these are used at the rate of ½ to 1 pint per 100 gallons of water.

Very little is known concerning the plant toxicity of this chemical. A number of woody plants appear to be tolerant, but begonias, ferns, and other tender plants are apt to be severely injured.

Caution. Dimethyl carbinol is poisonous and should be handled with care.

Spray particles should not be inhaled, and the eyes and skin should be protected.

DINITRO-PHENOL COMPOUNDS

Dinitro-phenol compounds have been used to some extent for the control of spider mites. The dusts and spray materials available consist of dinitro-ortho-cyclohexylphenol or the dicyclohexylamine salt of this compound.

Two applications, about ten days apart, are reported to give satisfactory control of spider mites, the kill being slow. Considerable damage, however, may be expected to the foliage and flowers of greenhouse crops, particularly under conditions of high temperature and humidity.

Caution. The dinitro-phenol compounds are poisonous and should be handled with care. Spray or dust particles should not be inhaled.

ETHYLENE DIBROMIDE

Ethylene dibromide, commonly referred to as EDB, is one of the most promising of the new soil fumigants, but it cannot be used with living plants. It has been effective in controlling the garden centipede, wireworms, nematodes, and other soil pests.

It is a colorless liquid which is commercially available as a 10 to 25 per cent solution in petroleum thinners. It is most effectively used in beds by means of a hand applicator which injects measured quantities into the soil. About 2 ml. (cc.) of 10 per cent material is drilled 6 or 8 inches into the soil at 12-inch intervals. The soil should be in a condition ready for planting, moist but not wet. Crops should not be planted for a week to ten days following treatment.

Caution. EDB is poisonous and should be handled with care.

FLUORINE COMPOUNDS

Cryolite

Cryolite is a complex fluoride containing both sodium and aluminum, and it is often called "sodium fluoaluminate." It is mined from natural deposits, but synthetic material also is available commercially.

Cryolite is only slightly soluble in water but may cause burning under moist greenhouse conditions. It has been used to some extent against earwigs and certain beetles and caterpillars, usually as a 40 or 50 per cent dust or as a 50 to 90 per cent wettable powder. The 90 per cent material is used at a rate of from 3 to 5 pounds per 100 gallons of water.

Sodium Fluosilicate

Sodium fluosilicate has often been used as the toxic ingredient of baits, particularly for earwigs and cutworms. It is used in about the same proportion as that given for arsenic trioxide.

Caution. Fluorine compounds are poisonous and should be handled with care.

MERCURIC CHLORIDE

Mercuric chloride, also called corrosive sublimate, is an extremely poisonous compound which has been used for certain soil pests such as root maggots. It is used at a dilution of 1:1,000 (1 ounce mercuric chloride per 8 gallons of water) when it is sprinkled over the soil. Tablets may be obtained at a drugstore which will make 1 pint of solution. Dilution should be made with distilled water, and the solution must not be kept in a metal container.

Care should be taken during application to keep the liquid off foliage. Its deleterious effects on plants may not be evident for many months.

Caution. Mercuric chloride must be handled carefully because of its great toxicity to man and animals.

METALDEHYDE

The use of metaldehyde has been confined to baits and to the control of slugs and snails. The most satisfactory mixtures for this purpose consist of 1.5 to 2.5 per cent of powdered metaldehyde and

5 per cent calcium arsenate in bran, along with other ingredients such as fruit pulp, molasses, raisins, or boiled potatoes. The mixture is moistened to form a mash and broadcast lightly over the soil, but not on the plants. Many commercial slug and snail baits are available in pellet, granular, or powder form, and these are usually successful in keeping the populations down.

METHYL BROMIDE

Methyl bromide is a fumigant of considerable importance for the treatment of greenhouse plants, nursery stock, and bulbs. It is a gas at ordinary temperatures, but it is easily liquefied. This product is commercially available in ½- or 1-pound cans or in quantities of 10, 50, and 150 pounds in light metal cylinders. The vapor is heavier than air, and it is nonexplosive. *It is very toxic to man and lacks a distinctive odor at low but toxic concentrations.*

It is less injurious to plants than most fumigants and highly toxic to all forms of insect life including the eggs, but evidence of its insecticidal action may be delayed for as long as several weeks following fumigation. Methyl bromide has proved to be outstanding for the control of scale insects, mealybugs, cyclamen mite, and other pests which are difficult to control.

Fumigation Chambers. Because methyl bromide readily dissipates from small leaks, it is usually used in air-tight fumigation chambers. Such chambers should be equipped with a heater to permit temperature control, and insulated to avoid temperature fluctuations. Methyl bromide is introduced from outside the chamber through copper tubing which enters near the ceiling, and stratification of the vapors will result unless fans are provided for air circulation. The chamber should be loaded so as not to interfere with the circulation. A humidifier should be used, since a relative humidity of 75 per cent or higher lessens considerably the danger of plant injury and probably enhances the insecticidal action. Caution should be used to avoid exposure of humans to the gas following fumigation, and for this reason an evacuator should be provided for the chamber.

Dosage. There is a close relationship between the dosage used, the time of exposure, and the temperature under which the fumigation is carried out. The best temperature for fumigation is between 80° and 85° F, although somewhat lower temperatures may be used by increasing the dosage or the time of exposure. In this connection, one may consider ½ pound of methyl bromide to be equivalent to 10° F difference in temperature or ½ hour exposure time, once the lethal dosage has been established for other given conditions.

The dosage is also determined on a basis of the specific pests to be controlled and the tolerance of the plants to be fumigated. As a general rule, however, greenhouse plants are fumigated with 2 pounds of methyl bromide per 1,000 cubic feet for two hours when the temperature is from 80° to 85° F. For outside nursery stock, or dormant plants being brought into the greenhouse, 2½ pounds are often used under the same conditions. In this case, it is important to warm for several hours plants which have been in cold outside temperatures. Dormant bulbs may be subjected to 3 pounds under the same conditions.

Plant Tolerance. A great many plants are tolerant to methyl bromide fumigation, but banana, begonia, chrysanthemum, coleus, fish geranium, maidenhair fern, poinsettia, saintpaulia, stephanotis, and certain other plants may be severely injured. Plants which show initial injury but soon recover are fuchsia, hibiscus, hydrangea, and pelargonium.

Greenhouse Fumigation. Experimental studies have been conducted on the use of methyl bromide for fumigation directly in the greenhouse. Vaporization was obtained preferably by spraying the

liquid material into the house. Satisfactory control of a variety of pests was reported.

Methyl bromide emulsion is a good soil fumigant, particularly near living plants. Soil may be treated with a hand injector, and it may be planted safely within several days.

Caution. Its extreme toxicity to man makes great care necessary in the use of this fumigant.

NAPHTHALENE

Naphthalene is a white crystalline compound that may be obtained either as flakes or mothballs. It was used against spider mites in greenhouses in England as early as 1923, and formerly it was used to a considerable extent as a greenhouse fumigant in this country.

As a fumigant, from 2 to 3 ounces per 1,000 cubic feet are vaporized by heat, under temperatures between 75° and 85° F, and relative humidities between 75 and 80 per cent to avoid recrystallization on the plants. Several fumigations usually are necessary, and many plants are susceptible to injury.

Naphthalene is also effective against gladiolus thrips, and the flakes are used with bulbs for control of these insects.

OILS

Petroleum Oils

Petroleum oils that are used for spraying are derived from certain distillation fractions which are refined by removing most of the portion which reacts with sulfuric acid. The oils which are less toxic to foliage contain a higher percentage of this unsulfonated residue, usually from 90 to 98 per cent in the "light oils" or "foliage oils." The less volatile and more viscous oils (medium and heavy oils) are more effective as insecticides, but they are also more toxic to plants. They are used as dormant sprays on deciduous, hardy plants outdoors.

In order to secure a uniform film over the plant, oils are generally applied in the form of an emulsion (with small globules of the oil evenly dispersed in water). To provide the emulsion, commercial preparations usually contain an emulsifying agent either dissolved in the oil (emulsive type containing about 99 per cent oil) or else forming a concentrated stock emulsion (emulsion type containing about 83 per cent oil). The type and amount of emulsifying agent largely control the amount of oil that is deposited in spraying, as well as its compatibility.

Applications. Light-oil emulsions are used at a 1 to 2 per cent dilution for the control of mealybugs, soft scales, armored scales, and whiteflies in greenhouses. The amount of oil needed may be considerably reduced by the incorporation of an oil-soluble toxicant such as rotenone, nicotine, or DDT. These oil combinations are the ones most commonly used by nurserymen, and many plants are tolerant to several treatments a year. Certain tender plants, however, may be readily injured by oil.

Applications are generally in the form of a fine spray. Potting plants are sometimes immersed into the agitated emulsion and then laid on their sides to drain.

Vegetable Oils

Vegetable oils, such as coconut oil, are sometimes used instead of petroleum oils, particularly when such plant derivatives as rotenone are incorporated.

ORGANIC PHOSPHATES

Hexaethyl Tetraphosphate Tetraethyl Pyrophosphate

The insecticidal value of hexaethyl tetraphosphate or "HETP" was originally discovered in Germany where a formulation was called "Bladan." Then it was believed that hexaethyl tetraphosphate was the toxic material, and many commercial preparations have referred to the content of this chemical. It is now known that the active ingredient is tetraethyl pyrophosphate, which constitutes about 20 per cent of hexaethyl tetraphosphate.

Technical material referring to tetraethyl pyrophosphate, "TEP," or "TEPP," is composed of about 40 per cent of the active ingredient.

TEP or HETP are effective insecticides for many species of aphids and for the active stages of spider mites. The insecticidal phosphate breaks down rapidly in the presence of water and loses its effectiveness, and no residual action is obtained.

Formulations used as a spray are usually diluted at the rate of about ¼ pint (for 20 per cent TEP) per 100 gallons of water. Satisfactory results for greenhouse use have been obtained with aerosol applications, either by mechanically produced fogs or liquefied-gas aerosols. Steam-pipe fumigation has been practiced to some extent with this material.

Care must be exercised in the use of TEP to avoid plant injury. A wide variety of plants are tolerant to the recommended dosages, but heavier applications are apt to cause considerable burning. Certain plants such as cyclamen are very sensitive to TEP.

Caution. TEP and HETP are very toxic to man. The concentrate material must be handled with extreme care. Protection is necessary against the spray mist to avoid inhalation, contact with the eyes, or wetting of bare skin through which absorption may occur. Protective clothing and a respirator are necessary when applying a spray or mechanically-produced aerosol. Liquefied-gas aerosols should be applied only when using a gas mask provided with a filter for organic vapors as well as protective clothing.

The greenhouse must be thoroughly ventilated following aerosol or steam-pipe fumigation.

Parathion

Parathion is the accepted common name of diethyl-paranitrophenyl thiophosphate, and it also has been referred to under other designations such as "3422." The insecticidal value of parathion was originally discovered in Germany during the war. It promises to be one of the best insecticides yet developed for many pests encountered by the flower grower.

Parathion applications possess residual action for several days or for longer periods of time against very susceptible insects, but its lethal action against scale-like insects may not be evident for several weeks. Commercial preparations have a musty odor. Both wettable powders (15 and 25 per cent actual material) and dusts (½ to 5 per cent parathion) as well as liquefied-gas aerosols are available.

As a wettable powder, used at a rate of one pound of 15 per cent actual material per 100 gallons of water, parathion is effective for the control of all stages of thrips, aphids, whiteflies, and caterpillars. At the rate of 1½ to 2 pounds of 15 per cent actual material per 100 gallons of water, excellent control may be obtained for all the spider mites, mealybugs, active stages of the cyclamen mite under exposed conditions, and young stages of armored scales and soft scales.

Liquefied-gas aerosols are also available. Such an aerosol is used at the rate of one pound of 10 per cent (by weight) solution in methyl chloride per 50,000 cubic feet of greenhouse space.

Significant plant injury, including injury to delicate blooms, has not been observed with experimental materials on a great variety and large number of plants treated with parathion. However, maidenhair and Boston ferns, poinsettias, and one variety of azalea (Christmas Star), are susceptible to damage. Commercial preparations have not been used extensively, and the grower should treat a small sample first to satisfy himself as to the tolerance of the plants involved. It should not be used when active sulfur is present from sulfur fumigation, else considerable leaf drop is possible.

Caution. Parathion is a very toxic material and must be handled accordingly.

Spray mists or dusts must not be inhaled, and a respirator as well as protective clothing should be worn for spray and dust applications. In the case of using liquefied-gas aerosols a gas mask provided with a filter for organic vapors must be worn as well as protective clothing. The greenhouse should be thoroughly ventilated following use of parathion as a spray or as an aerosol fumigant.

ORGANIC THIOCYANATES

A number of organic thiocyanates are highly toxic to certain species of insects and mites and their action is very rapid. They are relatively nontoxic to man. The simplest one of practical value is lauryl thiocyanate, and this compound has shown some promise in the control of the cyclamen mite. The commercial preparation is used at the rate of ½ pint to 1 pint per 100 gallons of water.

The most widely used organic thiocyanate is β—butoxy—β′ thiocyanodiethyl ether. A 50 per cent solution of this compound in kerosene is sold as a fly spray concentrate, while a water-miscible concentrate has been prepared for greenhouse uses against such pests as mealybugs and whiteflies.

The thiocyanates are apt to be very injurious to plants at effective concentrations, but this danger may be reduced somewhat by syringing with water after each application.

PLANT DERIVATIVES

Nicotine

Nicotine is one of the oldest and best known insecticides. It is effective for many aphids, certain caterpillars, leafhoppers, and thrips. It is derived from various species of tobacco. *Nicotine itself is a fairly volatile and very toxic liquid which is readily absorbed by the human skin.* It reacts with many substances to form compounds which are nonvolatile and relatively nontoxic as long as they remain undecomposed. Alkaline substances cause the liberation of nicotine from its compounds.

Nicotine sulfate (40 per cent nicotine) is the chief form in which nicotine is used. This form is applied as a spray at the rate of about 1 pint per 100 gallons, with the addition of a liberal amount of soap (such as 1 gallon liquid fish-oil soap) or other spreaders and stickers. It is also commonly used in oil preparations.

A wide variety of nicotine dusts are available, with different strengths of nicotine (usually 1 to 4 per cent) and with a large assortment of carriers. The alkaline carriers cause a more rapid liberation of the nicotine, while neutral carriers favor a release which is slower and over a longer period of time. High temperatures favor the evolution of nicotine from the dusts. Combination dusts are available in which nicotine is included with other insecticides or fungicides.

Nicotine as a fumigant also has been used in greenhouses. Liquid nicotine is painted on cold steam pipes and then volatilized by turning on the heat, or else it is volatilized from special heating containers distributed throughout the house. Nicotine powder preparations are also available in cans which can be ignited to release nicotine with the smoke.

Many delicate flowers and tender shoots are subject to injury by nicotine as a spray, dust, or fumigant.

Caution. Because nicotine is very toxic to humans, it should be handled with care. Acute illness may be caused by inhalation of the fumes or by absorption of nicotine through the skin.

Rotenone

Rotenone is derived from the roots of certain legumes which occur in the tropics. These plants sometimes are called derris, cubé, or timbo. It is not known to be very harmful to humans, although hypersensitive individuals may suffer skin irritation.

Rotenone serves as either a contact or stomach poison, and its action is slow.

It is used against various insects including aphids and certain caterpillars and beetles. It is applied either as a spray or as a dust, various concentrations being present (usually 0.5 to 5.0 per cent) in commercial products. It also is incorporated in oil sprays.

Pyrethrum

Pyrethrum is derived from the flowers of the pyrethrum plant, a member of the genus *Chrysanthemum*. It is not generally toxic to man, and it is nontoxic to plants. The insecticidal ingredients are four complex compounds which are known as pyrethrins and cinerins.

Pyrethrum is known particularly as a household insecticide, but it also is used for pests of ornamentals, including aphids, thrips, and leaf tiers. The active ingredients are volatile and deteriorate rapidly, and they break down in the presence of alkalies. Spray concentrates and dusts with varying pyrethrum content (usually 0.1 to 3.0 per cent) are used, as well as mixtures in oil or liquefied-gas aerosols.

Sabadilla

Sabadilla is derived from the seeds of a South American liliaceous plant. It has been used to some extent for the control of plant bugs and leafhoppers, as well as certain caterpillars and fungus gnats. Dusts (10 or 20 per cent) are used mostly, but spray materials are also available. Sabadilla is not toxic to plants or animals, but it does cause sneezing.

SELENIUM COMPOUNDS

Sodium Selenate

Sodium selenate, when applied to the soil, is taken up by plants and accumulates in the foliage. It is used rather extensively on carnations for the control of spider mites and aphids. Other crops such as chrysanthemums, saintpaulias, and hydrangeas are sometimes treated. Sufficiently toxic quantities are not accumulated in woody plants to give pest control.

Sodium selenate may be obtained in pure form with which a stock solution is prepared by dissolving 1 pound in 4½ gallons of water (100 grams per gallon). One quart of the stock solution is diluted with 25 gallons of water and evenly sprinkled over 100 square feet of bench area.

A dry form is also available which consists of 2 per cent sodium selenate impregnated on superphosphate. Three pounds of this solid material are broadcast evenly over 100 square feet of bench area and watered into the soil carefully.

Treatment with sodium selenate either as a solution or solid should not be made until after plants are well established, about one month after benching, and from two weeks to two months are required for the plants to absorb insecticidal quantities. A single application may then remain effective for 9 to 12 months on carnations. Great care should be taken to give the proper dosage. In too large a dose sodium selenate may produce stunting on chrysanthemums, and it will produce severe injury to plants such as cyclamen and begonia.

Caution. Sodium selenate is very toxic to humans, and it should be handled with great care.

SULFUR

Elemental Sulfur

This form of sulfur has been used extensively for the control of spider mites. Dusting sulfur is made free flowing by the addition of a small amount of inert powder, and it is often incorporated in other insecticidal dusts. Extreme fineness of the sulfur particles enhances the effectiveness. Preparations of sulfur can be obtained in which a wetting agent has been added, so that water suspensions may be used for spraying.

Sulfur may be injurious to plants, particularly under high temperatures, and *oil should not be used while sulfur is on the plant.*

Lime-Sulfur

Lime-sulfur is a reactive solution of lime and sulfur. It contains a high percentage of calcium polysulfides which break down after spraying to form very fine particles of sulfur. Both liquid concentrates and wettable powders are available commercially. It has been used to some extent in greenhouses for cyclamen mite control.

Lime-sulfur is very likely to cause foliage injury, particularly in hot weather. It will discolor paint or cement work.

Ammonium Polysulfide

Commercial preparations of ammonium polysulfide have been used to a limited extent for control of the cyclamen mite.

TARTAR EMETIC

Tartar emetic is an antimony compound known as potassium antimonyl tartrate. It has been used with brown sugar incorporated into a spray as a poisonous bait for the control of thrips, and it has been used in ant baits.

Certain thrips, notably the citrus and greenhouse thrips, apparently have developed resistance to tartar emetic, and newer insecticides have for the most part replaced it.

TOXAPHENE

Toxaphene, or chlorinated camphene, is a chlorinated terpene hydrocarbon. It is a cream-colored, waxy material with a pine-like odor. It is readily soluble in organic solvents, and is available as an emulsion concentrate, wettable powder, or dust.

Toxaphene is a relatively new insecticide, and its advantages or usefulness on greenhouse insects have not been determined. It is reported, however, to be effective against a number of agricultural pests such as certain beetles, caterpillars, thrips, and leafhoppers. There is a considerable residual action, and plant tolerance appears to be generally good.

Toxaphene is reported to be less toxic to warm-blooded animals than DDT, but it should be handled with care until the hazards are better understood.

Tables of equivalents for diluting liquid and solid insecticides in water are given on page 72.

METHODS FOR *Applying* INSECTICIDES

DUSTS

In the preparation of dusts, finely ground particles of a solid insecticide are mixed with a suitable powdered diluent, or else the insecticide is impregnated on a powdered diluent carrier. Dust diluents or carriers include such materials as pyrophyllite, kaolin, bentonite, and talc. Certain arsenicals, benzene hexachloride, chlordane, DDT and related compounds, parathion, plant derivatives, and sulfur may be used as dusts. The insecticidal concentration in dusts is generally from 0.5 to 10 per cent.

Dusting Equipment

Dusts are usually applied in greenhouses by means of hand-operated dusters. Both the rotary type and the bellows type are available, but the former is easier to handle in narrow aisles. The dusting apparatus must be adjusted so that an even coverage is possible, and it should be operated so that a very light but thorough coverage is obtained. It is sometimes practical when dusting the soil in small beds or individual pots to use a shaker made from a fruit jar with small holes punched in the lid.

SPRAYS

Nearly all of the insecticides which are sprayed on plants are but sparingly soluble in water. Special preparations are necessary, therefore, in order to dilute the insecticides with water to provide a spray which will evenly distribute small quantities of the material over the plants. There are two general types of such spray materials: wettable powders and emulsions.

Wettable powders are solid particles either composed of or impregnated with the insecticide to which has been added a wetting agent. Such powders form suspensions in the water with which they are mixed. Lead arsenate, benzene hexachloride, chlordane, DDT and related compounds, parathion, and sulfur may be obtained as wettable powders.

Emulsions are insecticides which are dissolved in an organic solvent with the addition of an emulsifying agent. These emulsions form small globules in the water with which they are mixed. Chlordane, DDT and related compounds, organic phosphates, oils, and thiocyanates are used commonly as emulsions.

Wettable powders or emulsions must be thoroughly mixed and continually agitated while spraying. Nicotine sulfate, however, is readily soluble in water, and it forms a true solution when diluted.

Spreaders and wetting agents are often used in sprays to provide even coverage of the foliage, but the use of too much adjuvant of this type will result in excessive run-off. Stickers are used in sprays to increase the persistence of the deposit.

Spraying Equipment

Various types of spraying equipment are in current use. The hand-operated sprayers are convenient for small greenhouses or for spot treatment. A 3-gallon, pressure type, knapsack sprayer is convenient for carrying along narrow aisles. This type is pumped up by hand before spraying, and must be repumped when the pressure drops. It must be shaken often because it contains no agitator.

A 15-gallon wheelbarrow-type sprayer is often used for small jobs. With this type of apparatus, one man operates the handle of the pump while another does the spraying.

A power-operated sprayer is an indispensable piece of equipment for many nurserymen. From 25- to 50-gallon portable models are satisfactory for most

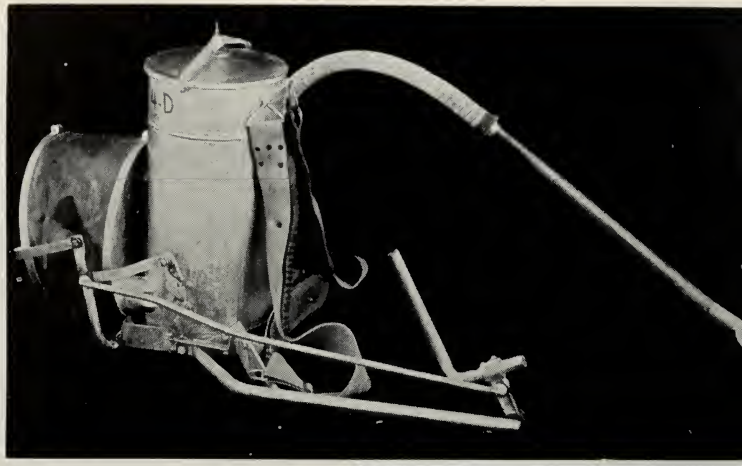
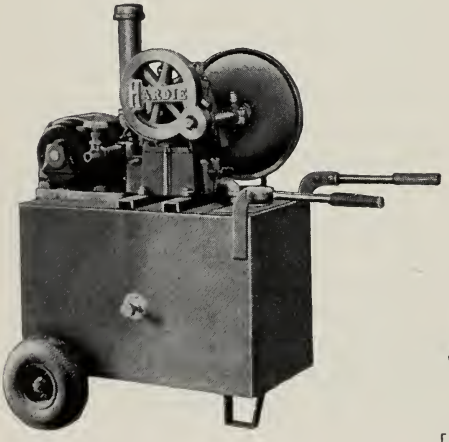


Fig. 53. **Dusting equipment** of two satisfactory types is shown above: at left, the rotary type which is easy to handle in narrow aisles; at right, the bellows type worn on the back.

Spraying equipment convenient for greenhouse use includes the three shown here. Right, the 3-gallon pressure type knapsack sprayer; below left, a power-operated sprayer with larger capacity; below right, a 15-gallon wheelbarrow type.



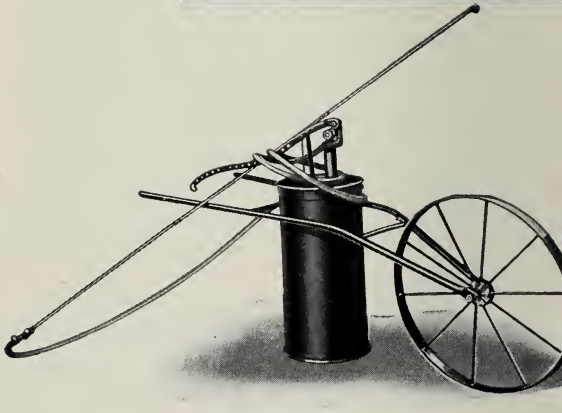


Fig. 54. A portable model of fog-generating machine produces very fine particles, necessary in this method of pest control.

greenhouse work. In some of the larger establishments a sprayer with a much larger capacity is installed, and outlet pipes are laid to the various greenhouses.

The amount of pressure necessary for satisfactory coverage varies mainly with the type of spray equipment, the type and number of nozzles, and the size of the disc openings. In general, nozzles preferable for greenhouse use are those which give a fan-type spray or else a solid cone.

FOGS

Spray concentrate solutions may be forced through an atomizer with the aid of compressed air, so that very small droplets are formed. These tiny droplets will form an aerosol fog or mist when sufficient compressed air is used for propulsion. Such insecticidal fogs have proved to be effective means of control in greenhouses when the particles are very fine and adequately dispersed. This method has been particularly popular for application of tetraethyl pyrophosphate.

Fog-generating Equipment

To produce fogs, a power-operated compressor may be used with a conventional atomizer. Small greenhouses can be treated from the entrances with such equipment. Hand-operated units for high-pressure atomization are available, these being carried through the greenhouse. Fog-generating machines are made which utilize the engine exhaust as an aid in producing the fog. The portable models of these machines must be pulled through the greenhouse in order to obtain coverage.

The discharge nozzle for fog fumigants should be directed so as to avoid immediate contact with plants because the larger droplets, which settle out first, may cause

burning. Wind currents should be considered in the plan of release so that uniform coverage of the house may be obtained. In general the rate of application is similar to that necessary with a given amount of spray for the same coverage.

The operator must take proper precautions when he may be exposed to fogs of poisonous materials. A suitable gas mask, protective clothing, hat, and gloves must be worn. The same precautions are necessary as in the application of liquefied-gas aerosols.

LIQUEFIED-GAS AEROSOLS

An aerosol is a dispersion of very fine particles in the air. The term, however, is applied particularly to the dispersion obtained from release of a solution of insecticide in a liquefied gas. When pressure on the liquefied gas is released it is vaporized and particles of the insecticide are left suspended in the air. Freon-12 and methyl chloride are commonly used as the solvents in aerosol preparations for greenhouse purposes.

Liquid-gas aerosols are available which contain benzene hexachloride, DDT, rotenone, organic phosphates, and pyrethrum. Lauryl thiocyanate aerosols have been used under experimental conditions. These aerosols are especially suited to enclosed conditions. Because of the ease, speed, and efficiency of application, they are expected to become of major importance for the control of greenhouse pests.

Dispensers

The hand dispensers which commonly are used consist of metal cylinders provided with valve and nozzle and containing the liquid-gas solution under high

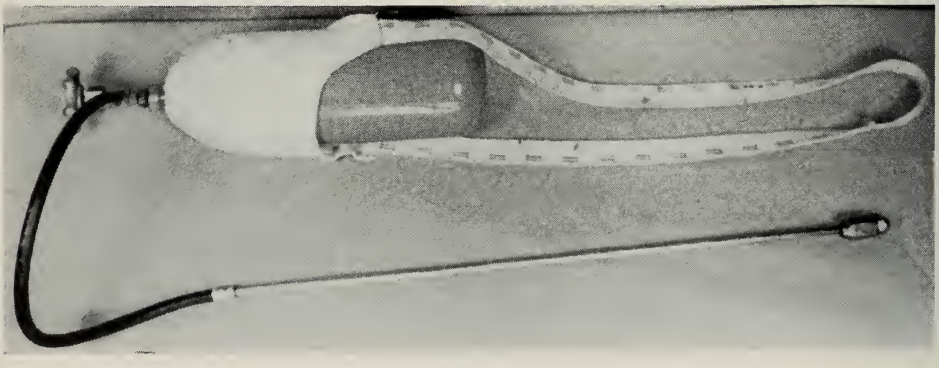


Fig. 55. Right, fumigation of a greenhouse by means of a liquefied-gas aerosol. Below, a hand dispenser commonly used.

Fig. 56. A pressure-fumigator can emitting smoke for greenhouse fumigation.

pressure. Low-pressure cans, employing other solvents, are being developed. Bottles are also expected to become available which will contain the liquid-gas solution under relatively low pressure. Such bottles are heated in an electric jacket to raise the pressure for application, and an applicator rod is inserted in the cap for release.

Caution. Methyl chloride, as well as such insecticides as the organic phosphates, is very poisonous. The operator applying these materials must wear a gas mask with a canister designed for protection against organic vapors (for example, the industrial full-vision gas mask made by the Mines Safety Appliance Company, or similar Army or Navy gas masks, provided with GMC-1 or GMA canisters for organic vapors). Protective clothing, rubber gloves, and hat also should be worn.

SMOKES

Smokes are aerial suspensions of very fine particles which are produced by the incomplete combustion of organic material. Smoldering powders that are composed of tobacco powder and potassium nitrate (saltpeter) and containing nicotine or azobenzene are often used in greenhouses.

Preparations which are used in cans are referred to as "pressure fumigators." For application, scored holes are punched in the can and the contents ignited. High temperature and pressure are then developed in the can, and clouds of smoke stream from the openings. Candles are also available which slowly smolder to produce the insecticidal smoke. Condensation of the azobenzene or nicotine vapors on the smoke particles renders this method of application somewhat safer on plants than their use as a gas, particularly when a sudden drop of temperature is experienced.

GASEOUS FUMIGATION

A fumigant is an insecticide which acts upon the insect as a gas. Liquid or crystalline materials which are used for greenhouse fumigation must be volatile enough to produce a toxic concentration of the vapor.

Calcium cyanide is one of the most widely used materials, and the toxic fumes are released by moisture in the air. Nicotine and naphthalene were formerly used extensively, while azobenzene and tetraethyl pyrophosphate have been used during recent years. Ready vaporization of these compounds is accomplished by means of heat from hot plates or steam pipes. Studies also have been made on the use of dichloroethyl ether and methyl bromide for greenhouse fumigation. Methyl bromide is a very effective fumigant which ordinarily is employed in fumigation chambers.

Successful greenhouse fumigation is generally dependent upon proper temperature and moisture conditions and proper exposure time. The dosage of a given material is subject to variation according to the tightness of the greenhouse and wind conditions. Gaseous fumigants are poisonous, and every precaution should be taken in their use.

SOIL TREATMENT

There are a number of materials which have been used for the fumigation of soil pests. Calcium cyanide, carbon disulfide, dichloroethyl ether, naphthalene, paradichlorobenzene, chloropicrin, and others have been used with varying degrees of success. Applications of these chemicals generally have been by spraying or sprinkling the surface of the soil. Where it is possible to treat bare soil, steam sterilization is generally effective.

Ethylene dibromide and D-D have proved to be the most satisfactory chemicals for treatment of bare soil. Methyl bromide emulsion can often be used when living plants are nearby. These, as well as other liquid soil fumigants, are most satisfactorily applied by means of a hand-operated gun which injects regulated dosages into the earth.

Benzene hexachloride and chlordane are the most promising materials for many soil pests (except mealybugs and nematodes) where treatment of the plants is also involved. These soil fumigants must be mixed with heavy soils, but they may be dusted or sprayed on light soils and watered in.

BAITS

Baits have been used extensively for the control of such pests as earwigs, sowbugs, cutworms, slugs, millipedes, brachyrhinus weevils, and ants. Materials such as the more soluble arsenicals and fluorine compounds and tartar emetic have been used as the toxic ingredients of varous formulae. In general these baits are effective in reducing populations, but elimination of the pests is rarely obtained. The newer insecticides, such as benzene hexachloride, DDT, and chlordane dusts or sprays, have largely replaced the baits for all of these pests except snails and slugs. The metaldehyde and calcium arsenate baits are still in general use for their control.

In order that the information in our publications may be more intelligible it is sometimes necessary to use trade names of products or equipment rather than complicated descriptive or chemical identifications. In so doing it is unavoidable in some cases that similar products which are on the market under other trade names may not be cited. No endorsement of named products is intended, nor is criticism implied of similar products which are not mentioned.

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TABLES OF EQUIVALENTS

TABLE 1. EQUIVALENT QUANTITIES FOR LIQUID INSECTICIDE DILUTIONS IN WATER

Dilution	100 gal.	50 gal.	25 gal.	12½ gal.	10 gal.	6¼ gal.	5 gal.	3⅛ gal.	2½ gal.
1:50 (2%)	2 gal.	1 gal.	2 qt.	1 qt.	1.6 pt.	1 pt.	12.8 oz.	½ pt.	6.4 oz.
1:100 (1%)	1 gal.	2 qt.	1 qt.	1 pt.	12.8 oz.	½ pt.	6.4 oz.	4 oz.	3.2 oz.
1:200	2 qt.	1 qt.	1 pt.	½ pt.	6.4 oz.	4 oz.	3.2 oz.	2 oz.	1.6 oz.
1:400	1 qt.	1 pt.	½ pt.	4 oz.	3.2 oz.	2 oz.	1.6 oz.	1 oz.	0.8 oz.
1:600	1½ pt.	¾ pt.	6 oz.	3 oz.	2.4 oz.	1½ oz.	1.2 oz.	¾ oz.	0.6 oz.
1:800	1 pt.	½ pt.	4 oz.	2 oz.	1.6 oz.	1 oz.	0.8 oz.	½ oz.	0.4 oz.
1:1600	½ pt.	4 oz.	2 oz.	1 oz.	0.8 oz.	½ oz.	0.4 oz.	¼ oz.	0.2 oz.
1:3200	4 oz.	2 oz.	1 oz.	½ oz.	0.4 oz.	¼ oz.	0.2 oz.	⅛ oz.	0.1 oz.

1 teaspoon	= ⅓ tablespoon	= 0.17 ounce	1 pint	= 2 cups	= ½ quart
1 tablespoon	= 3 teaspoons	= ½ ounce	1 quart	= 2 pints	= ¼ gallon
1 ounce	= 2 tablespoons	= ⅛ cup	1 gallon	= 4 quarts	
1 cup	= 8 ounces	= ½ pint			

TABLE 2. EQUIVALENT QUANTITIES FOR SOLID INSECTICIDE DILUTIONS IN WATER

100 gal.	50 gal.	25 gal.	12½ gal.	10 gal	6¼ gal.	5 gal.	3⅛ gal.	2½ gal.
4 oz.	2 oz.	1 oz.	½ oz.	0.4 oz.	¼ oz.	0.2 oz.	⅛ oz.	0.1 oz.
½ lb.	4 oz.	2 oz.	1 oz.	0.8 oz.	½ oz.	0.4 oz.	¼ oz.	0.2 oz.
1 lb.	½ lb.	4 oz.	2 oz.	1.6 oz.	1 oz.	0.8 oz.	½ oz.	0.4 oz.
2 lb.	1 lb.	½ lb.	4 oz.	3.2 oz.	2 oz.	1.6 oz.	1 oz.	0.8 oz.
3 lb.	1½ lb.	¾ lb.	6 oz.	4.8 oz.	3 oz.	2.4 oz.	1½ oz.	1.2 oz.
4 lb.	2 lb.	1 lb.	½ lb.	6.4 oz.	4 oz.	3.2 oz.	2 oz.	1.6 oz.
5 lb.	2½ lb.	1¼ lb.	¾ lb.	8 oz.	5 oz.	4 oz.	2½ oz.	2 oz.

1 pound = 16 ounces.

Use of Spoonfuls: The weight of solid insecticides varies so greatly that it is not possible to give accurate measures in terms of teaspoons, tablespoons, or cups. There are usually from 2 to 6 level tablespoons of these dry materials per ounce.